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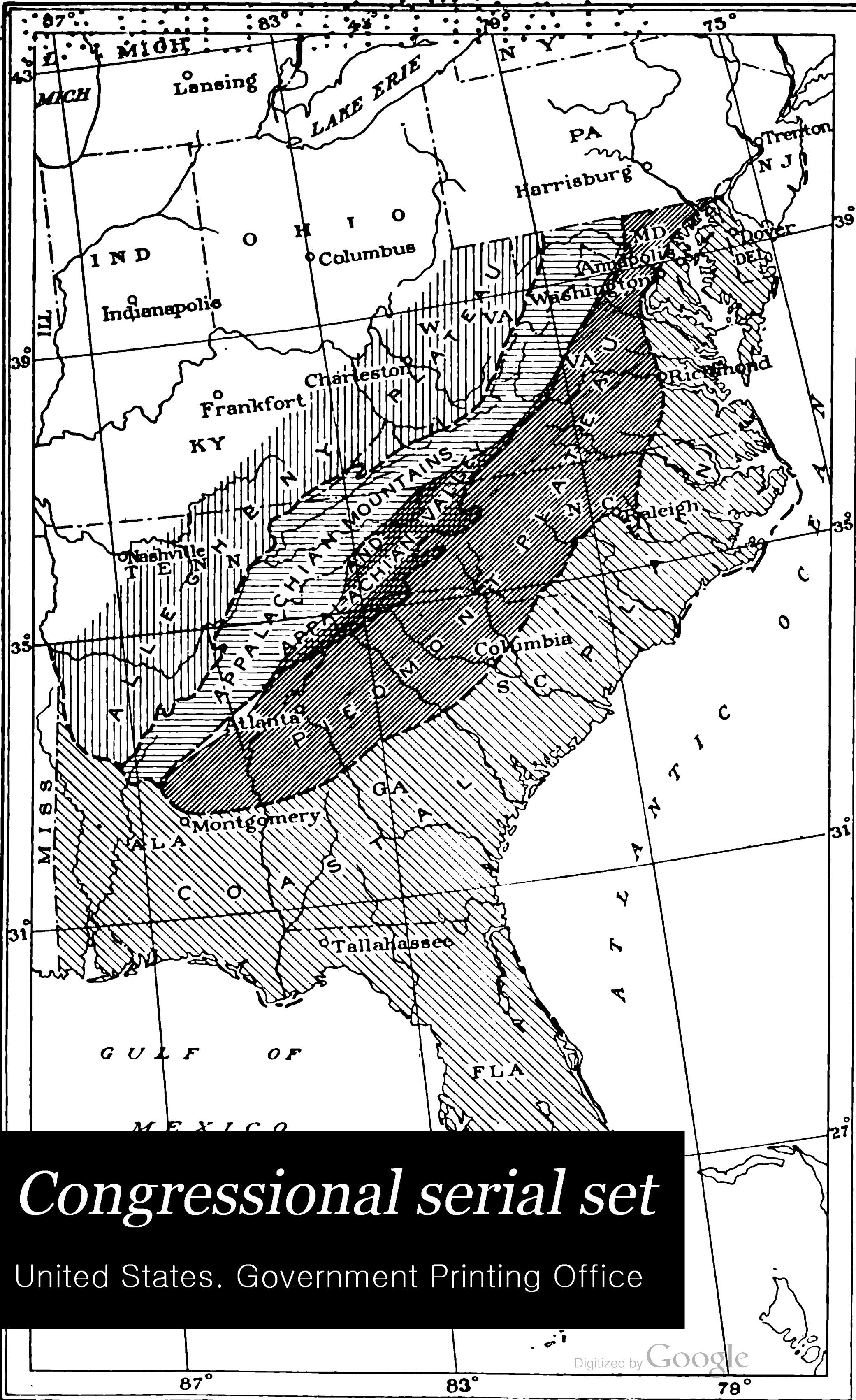

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Same 429; Oil and gas in Louisiana.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
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BULLETIN 426

GRANITES OF THE SOUTHEASTERN ATLANTIC STATES

BY

THOMAS LEONARD WATSON

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GRANITES OF THE SOUTHEASTERN ATLANTIC STATES.

By THOMAS LEONARD WATSON.

INTRODUCTION.

Economically, granite is the most important rock in the crystalline region of the Atlantic States south of Susquehanna River. Areally, it is one of the dominant rock types the distribution of which is shown on the map (fig. 1). Commercially, it is produced in this region in Georgia, Maryland, North Carolina, Virginia, and South Carolina, the five States being named in the order of their production. No production is reported from Alabama and Tennessee. The statistics on pages 270, 271 of this report indicate the annual value of the granite industry in these States to be about $3,500,000, or about 20 per cent of the granite output of the entire country.

In Bulletins 313 and 354, published in 1907 and 1908 by the United States Geological Survey, the granites of Maine and of Massachusetts, New Hampshire, and Rhode Island were described by T. Nelson Dale from both the scientific and the economic standpoint. The present work similarly describes the granites in the Atlantic States south of Pennsylvania, including Maryland, Virginia, North Carolina, Tennessee, South Carolina, Georgia, and Alabama. Chapter I contains a scientific discussion of granite adapted to the general reader, with special reference to the granites of the region described; in later chapters the occurrences are considered by States, the matter relating to each State being subdivided into a scientific part treating of the granite in that particular State and an economic part describing individual granite areas and quarries.

The field work on which this report is based was done in 1898, 1899, and 1903 for the state geological surveys of Georgia and North Carolina and in parts of the years 1905 to 1908, inclusive, for the United States Geological Survey. During this time the writer visited the granite quarries in each State described. The petrographic work included the study of more than 600 thin sections of typical rocks.

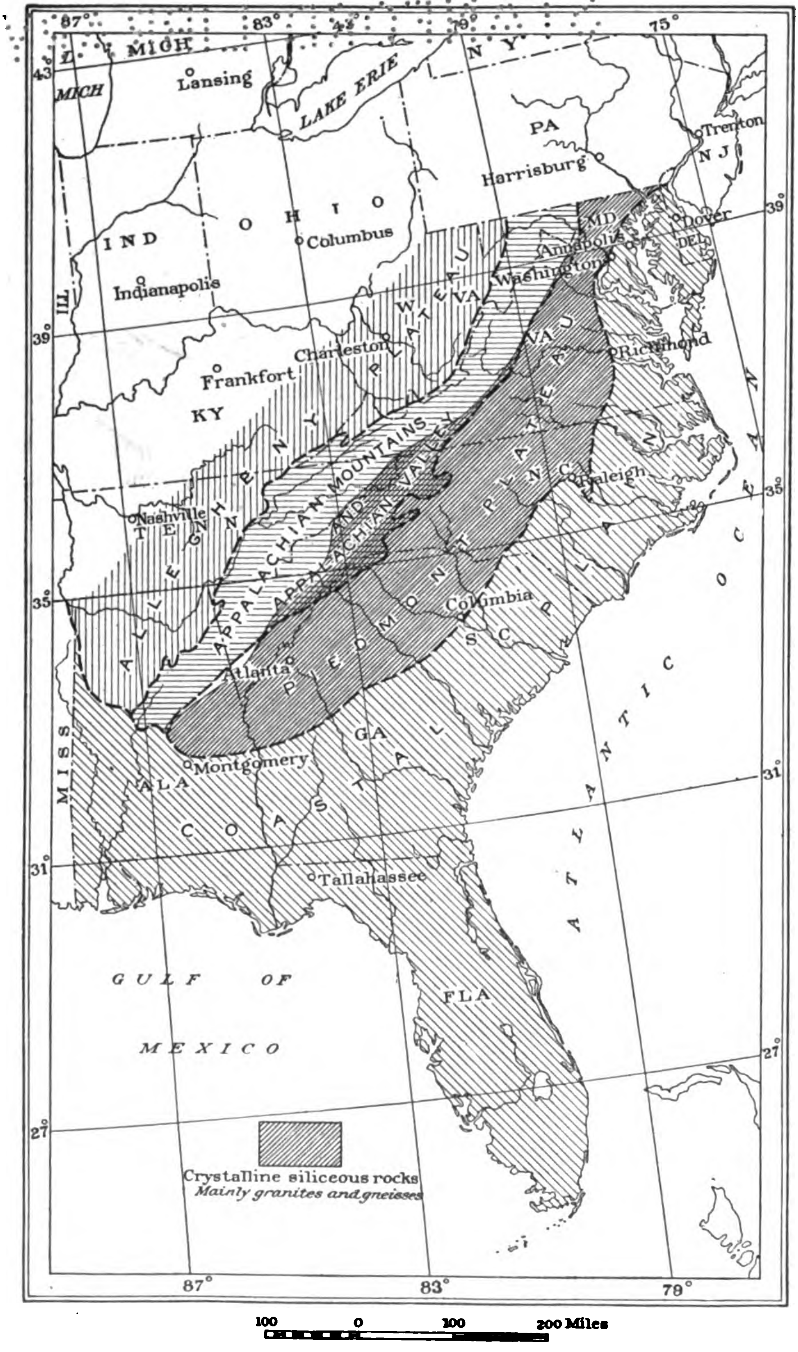

FIGURE 1.—Map showing distribution of granite in crystalline region of South Atlantic States.

The writer is indebted to the published reports on granite by the state geological surveys of Georgia, North Carolina, Maryland, and South Carolina, which he has used freely in the preparation of those parts of the report treating of the granite of these States. Much helpful information has been derived from Bulletins 313 and 354 of the United States Geological Survey on the granites of Maine, Massachusetts, New Hampshire, and Rhode Island, by T. Nelson Dale, and from the works of Merrill, Geikie, and Buckley.

To Professors Clark and Mathews, of the Maryland Geological Survey, the writer is indebted for the loan of thin sections of the Maryland granites in the geologic collections of Johns Hopkins University, and of Plate IV, *A*; to Dr. Joseph Hyde Pratt, state geologist of North Carolina, for the loan of Plate XX; to Dr. George P. Merrill, of the United States National Museum, for the loan of Plates XV and XVIII; to the Mount Airy Granite Corporation for the loan of Plate XIX; and to Mr. R. E. McClenahan, of Port Deposit, Md., for Plate VI, *A*. Miss A. T. Coons, of the United States Geological Survey, has contributed the statistical tables of granite production.

The word "granites" in this report is restricted to the quartz-bearing plutonic rocks, and includes both the massive and the schistose forms of even-granular and porphyritic textures. The only exceptions are in North Carolina, the augite syenite, leopardite (quartz porphyry), and orbicular gabbro-diorite occurring in that State being briefly described. The so-called "black granites" are not discussed.

CHAPTER I.

GRANITE IN GENERAL.

SCIENTIFIC DISCUSSION.

DEFINITION.

Granite is the family name applied to a large and common group of entirely crystalline igneous rocks, consisting essentially of quartz and potash feldspar (orthoclase or microcline, or both); more or less plagioclase feldspar—albite (soda feldspar) or oligoclase (soda-lime feldspar), usually the latter, or both—is generally present. Besides these minerals, which make up the mass of the rock, there is as a rule a small amount of either white mica (muscovite) or black mica (biotite), or both, locally hornblende, and here and there pyroxene. Each of these is evident to the eye without the aid of a lens.

Normally, granite is a massive rock without foliation or banding. When it takes on a foliated or banded structure, subsequent to its crystallization, it is no longer a true granite, but a granite gneiss.

MINERAL COMPOSITION.

The light-colored minerals, feldspar and quartz, are the essential minerals in granite and make up the mass of the rock. Of these, feldspar is the more conspicuous and generally the more abundant. It is readily distinguished by having two cleavages inclined at an angle of 90° or nearly 90°, the cleaved surfaces being smooth and brilliantly reflecting. The mineral is usually white, gray, or pinkish, but is sometimes green. Two kinds of feldspar are generally present, the more abundant of which is usually potash feldspar, a silicate of alumina and potash. This may be either orthoclase or microcline, or both, distinguished only by means of the microscope. The other feldspar (plagioclase)—albite (soda feldspar) or oligoclase (soda-lime feldspar), or both, but usually oligoclase—can generally be distinguished from the potash feldspar by the fine parallel lines on its basal surface. The potash and soda-lime feldspars are readily distinguishable from each other under the microscope. The granites which form the subject of this bulletin are generally characterized by nearly equal proportions of potash and soda-lime feldspars and are, technically, quartz monzonites.

Quartz is the next most abundant mineral and is readily distinguished by its glassy luster, uneven fracture, and brittleness. It is colorless, gray, or dark smoky, less commonly bluish or opalescent.

Mica, the third most abundant mineral in granites, may be present in two forms—white (muscovite or potash mica) and black (biotite or iron-magnesia mica). One or both of these minerals may be present in granite, and they are alike in cleaving along one direction into thin elastic folia, a property by which they are easily distinguished from the other constituents. They are distinguished from each other by their color. With only a few exceptions the granites described in this bulletin are mica granites. Biotite is much the commoner of the two micas, and granite containing biotite but no muscovite is sometimes called granitite.

Hornblende, a constituent of many granites, is much less common than mica in the granites here described. It may be as dark in color as the black mica (biotite), but it is readily distinguishable from biotite by the fact that it does not cleave into thin elastic scales, but possesses two cleavages inclined at an angle of approximately 124°. Augite and hornblende, when present in a granite, resemble each other so closely that they can at times be distinguished only by means of the microscope.

Besides these more important minerals which usually determine the character of the granite, others are present in microscopic proportions and are usually called minor accessory minerals. Of these, minerals like zircon, apatite, magnetite, ilmenite, titanite, pyrite, garnet, allanite, rutile, tourmaline, and fluorite are regarded as original. Others, such as chlorite, epidote, kaolin, sericite, and calcite, are the result of chemical changes in the feldspars or the dark ferromagnesian minerals, or both, and are therefore secondary. In a few instances calcite has been regarded as an original mineral in granite.[a] With the exception of fluorite, all the accessory minerals enumerated have been found in the granites described in this bulletin.

Of the minor accessory minerals named, pyrite (iron disulphide) and calcite (calcium carbonate), when present in an exposed surface of granite, are harmful, the pyrite producing discoloration on oxidation and the calcite when dissolved causing weakness in the stone.

The relative proportions of the minerals in granite differ within rather wide limits for granites from different localities. The percentages of feldspar and quartz are large, while that of the bisilicate minerals (micas, hornblende, and augite) is small. This variation in the percentages of the minerals is shown in the table below, which gives the mineral percentages of well-known granites.

---

[a] Bull. U. S. Geol. Survey No. 313, 1907, p. 17, references cited.

Percentages of minerals in various granites.

Constituents.		1.	2.	3.	4.	5.	6.	7.	8.	9.
Feldspar	Orthoclase	43	28	28.85	28.2	[a] 55.4	[a] 58.9	12.26	8.91	[b] 53.33
	Plagioclase	[c] 9	[d] 7	22.45	32.5	15.1	1.3	29.95	34.86	2.55
Quartz		44	59	44.65	35.5	26.0	28.5	33.82	42.28	33.41
Mica		[e] 4	6	4.05	[f] 3.3	3.3	10.3	17.83	10.41	10.71

[a] Reported as microcline chiefly, subordinate orthoclase.
[b] Reported entirely as microcline.
[c] Albite.
[d] Plagioclase.
[e] Biotite.
[f] Biotite, 1.3; hornblende, 2.0.

1. Red granite from Egypt.
2. Porphyritic granite from the Vosges. Prestwich, Jos., Geology: Chemical, physical, and stratigraphical, vol. 1, 1886, p. 42.
3. Biotite granite from Hardwood Island quarry, Maine. Dale, T. N., Bull. U. S. Geol. Survey No. 313, 1907, p. 173.
4. Hornblende granite from Rockport, Cape Ann, Massachusetts. Washington, H. S., Jour. Geology, vol. 6, 1898, p. 794.
5. Acidic granite from south end of Millstone Hill, Barre, Vt. Rept. State Geologist for 1901-2, 1902, p. 56.
6. Granite (medium stock) from eastern slope of Millstone Hill, Barre, Vt. Rept. State Geologist, 1901-2, 1902, p. 56.
7. Hornblende-biotite granite (quartz monzonite) from Cecil County, Md. Maryland Geol. Survey, 1902, p. 120.
8. Biotite granite (quartz monzonite) from Port Deposit, Cecil County, Md. Maryland Geol. Survey, 1902, p. 119.
9. Biotite granite from Platte Canyon, Jefferson County, Colo., Bull. U. S. Geol. Survey No. 150, 1898, p. 173.

The figures above indicate, as is usual, much variation in the relative proportions of the feldspar and the quartz, and to a greater extent in the potash feldspars (orthoclase and microcline) and the soda-lime feldspars (plagioclase). A careful examination, however, of the chemical analyses of the granites described in this bulletin discloses a smaller range in the relative amounts of the potash and soda-lime feldspars than is usual for normal granites from widely separated areas.

CHEMICAL COMPOSITION.

The chemical composition of granite, though conditioned by mineral composition, is now regarded to be of less economic importance than the latter. The chemical analysis corroborates the microscopic analysis. The analyses of granite here given will suffice to show the general range in composition.

Four analyses of granites from Scotland, Ireland, Italy, and Sweden give the following:

Analyses of European granites.[a]

Silica (SiO_2)	70.60–74.82
Alumina (Al_2O_3)	14.86–16.40
Ferric oxide (Fe_2O_3)	.10– 1.63
Ferrous oxide (FeO)	.36– 1.64
Manganese oxide (MnO)	.00– .48
Magnesia (MgO)	.23– 1.00
Lime (CaO)	.89– 2.47
Soda (Na_2O)	3.51– 6.12
Potash (K_2O)	3.55– 5.10

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[a] Geikie, Archibald, Textbook of Geology, 4th ed., 1903, vol. 1, p. 207.

Ten analyses made in the laboratory of the United States Geological Survey of granites from Arizona (1), California (4), Colorado (4), and Michigan (1), show the following ranges:

Analyses of ten United States granites.[a]

Silica (SiO_2)	66. 28–77. 68
Alumina (Al_2O_3)	11. 63–16. 38
Ferric oxide (Fe_2O_3)	.00– 2. 73
Ferrous oxide (FeO)	.09– 1. 88
Magnesia (MgO)	.04– 1. 63
Lime (CaO)	.12– 3. 75
Soda (Na_2O)	2. 85– 5. 16
Potash (K_2O)	1. 87– 6. 50
Titanium dioxide (TiO_2)	Trace– .54
Phosphoric oxide (P_2O_5)	Trace– .30

Analyses of granites from Maryland, South Carolina, and Georgia show the following ranges for the individual States:

Analyses of Maryland, South Carolina, and Georgia granites.

Constituents.	Maryland.[a]	South Carolina.[b]	Georgia.[c]
Silica (SiO_2)	62. 91–74. 87	62. 34–73. 26	63. 27–72. 56
Alumina (Al_2O_3)	12. 89–19. 13	13. 72–17. 22	14. 81–19. 93
Ferric oxide (Fe_2O_3)	Trace– 2. 07	.70– 1. 85	.94– 2. 85
Ferrous oxide (FeO)	.51– 3. 23	1. 24– 2. 49	
Magnesia (MgO)	.16– 2. 19	.22– 1. 30	.20– 1. 30
Lime (CaO)	.48– 4. 89	1. 28– 3. 28	1. 19– 3. 27
Soda (Na_2O)	1. 95– 3. 94	.55– 5. 39	4. 14– 5. 88
Potash (K_2O)	1. 48– 5. 36	2. 85– 6. 89	3. 29– 5. 85

[a] Eight analyses. W. F. Hillebrand, analyst.

[b] Thirteen analyses. Earle Sloan, analyst. Bull. South Carolina Geol. Survey, ser. 4, No. 2, 1908, pp. 177–223.

[c] Twenty-one analyses. Bull. Geol. Survey Georgia No. 9–A, 1902, pp. 241–242.

TEXTURE.

Texturally, granites are holocrystalline granular rocks. The crystalline granules (minerals) are in close contact and usually interknit. Granites, therefore, possess a minimum of pore space and a maximum degree of strength. Some granites are even grained; others contain prominently developed feldspars, with or without crystal outlines, embedded in a finer even-grained groundmass—that is, they are porphyritic in texture. The prominent or distinct crystals of feldspar are known as phenocrysts.

Difference in the magnitude of the minerals (granularity)[b] of even granites gives rise to a variety of texture. Three grades of texture may thus be distinguished—(1) coarse, in which the feldspars generally measure over 1 cm., or two-fifths inch; (2) medium, in which they measure under 1 cm. (two-fifths inch) and over 0.5 cm. (one-fifth inch); and (3) fine, in which they measure under 0.5 cm. (one-fifth inch).[a] In some coarse-grained granites the feldspars measure one or more inches and in some fine-grained ones as low as one-fiftieth inch.

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[a] Bull U. S. Geol. Survey No. 228, 1904, p. 197, analysis D; p. 231, analysis A; p. 232, analysis A; p. 240, analysis E; p. 241, analysis F; p. 185, analysis B; p. 161, analyses A, C, F; p. 78, analysis A.

[b] Cross, Iddings, Pirsson, and Washington, The texture of igneous rocks; Jour. Geology, vol. 14, 1906, pp. 694 et seq.

Under the microscope the arrangement of the minerals in granite shows that these have observed the following order in crystallizing out: (1) Minor accessory minerals (magnetite, apatite, zircon, titanite, pyrite, and ilmenite); (2) characterizing accessory minerals (hornblende, biotite, and muscovite); and (3) the essential minerals (feldspars and quartz). Examination of any medium or coarse-grained granite will show the quartz filling the spaces between the feldspars. Some of the earlier-formed minerals are, as a rule, partly or entirely inclosed by the later-formed ones (feldspars and quartz). In many granites the feldspars and quartz are intergrown, indicating overlapping in part of the periods of crystallization of these minerals.

PHYSICAL PROPERTIES.

Among the more important physical properties of granite are color, weight, strength, hardness, and porosity. These are briefly discussed in the order here named.

COLOR.

The usual color of granites is some shade of gray, though pink or red varieties are not uncommon. Color depends chiefly on the relative abundance of the dark ferromagnesian mineral or minerals (biotite or hornblende, or both) and the character of the feldspars. Those granites containing a large proportion of biotite or hornblende are of darker gray color than those containing but little. The pink and red colors are due to the presence of pink and red feldspars.

The Appalachian granites described in this bulletin are, with few exceptions, of some shade of gray varying from nearly white (Stone Mountain, Ga., granite), through medium gray (Richmond, Va., granites in part, and the Guilford, Woodstock, and Port Deposit, Md., granites), to dark blue-gray (Richmond and Fredericksburg, Va., granites in part; Winnsboro and Heath Springs, S. C., granites in part; and Oglesby, Ga., granite). A part of the granite of Dunns Mountain, near Salisbury, N. C., is of a pronounced beautiful pink color.

WEIGHT.

The specific gravity of a rock is the ratio of its density to that of an equal volume of distilled water at 4° C. (39.2° F.). The specific gravity of granite ranges from 2.593 to 2.731, with an average of

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[a] Dale, T. N., The granites of Maine: Bull. U. S. Geol. Survey No. 313, 1907, p. 20.

2.663. The weight of granite, expressed in pounds per cubic foot, is obtained by multiplying the specific gravity by 62.5, the weight in pounds of a cubic foot of distilled water at 4° C. (39.2° F.).

STRENGTH.

Hundreds of tests to determine the compressive strength of granite have been made. It will suffice here to direct attention only to the usual range in the ultimate compressive strength of granite, which is from 18,000 to 34,000 pounds per square inch. The range in ultimate compressive strength of the Wisconsin granites is, according to Buckley,[a] from about 15,000 to 43,973 pounds per square inch. For the compressive strength of the granites described in this bulletin, see pages 49–50, 149, 183, 213, 221, 252, 253.

HARDNESS.

By the hardness of a building stone is meant its resistance to wear. The principal factors which determine hardness are (1) aggregation of the constituent grains or the firmness with which they adhere, thereby diminishing proportionately the pore space; (2) actual hardness of the individual mineral grains; (3) size and relative abundance of the component minerals; and (4) mineral composition. Tests for hardness show that granites differ greatly. As stated by Dale,[b] "this difference is due not merely to differences in the percentage of quartz, but also to variations in the character of the feldspars."

POROSITY.

Fresh granite contains less than 1 per cent of water and is capable of absorbing a small fraction of a per cent more. According to Ansted[c] granite usually contains about 0.8 per cent of water and is capable of absorbing about 0.2 per cent more; a cubic yard of granite usually contains, therefore, 3.5 gallons of water. The pore space in 14 Wisconsin granites, as determined by Buckley,[d] ranges from 0.019 to 0.62 per cent, and the ratio of absorption of the same granites ranges from 0.04 to 0.50 per cent. According to Merrill[e] certain Maryland granites absorb from 0.196 to 0.258 per cent of water after drying twenty-four hours at 212° F. and then being immersed for twenty-four hours. The writer[f] found that the ratio of absorption of 12 Georgia granites ranged from 0.037 to 0.093 per cent.

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[a] Buckley, E. B., On the building and ornamental stones of Wisconsin: Bull. Wisconsin Geol. and Nat. Hist. Survey No. 4, 1898, pp. 361, 390.

[b] Dale, T. N., The granites of Maine: Bull. U. S. Geol. Survey No. 313, 1907, p. 22.

[c] Quoted by Hull, Edward, A treatise on building and ornamental stones of Great Britain and foreign countries, 1872, p. 30.

[d] Op. cit., p. 400.

[e] Merrill, G. P., Stones for building and decoration, 3d ed., p. 435.

[f] Watson, T. L., Granites and gneisses of Georgia: Bull. Geol. Survey Georgia No. 9–A, 1902, p. 351.

VARIETIES OF GRANITE.

Granites are usually classified, mineralogically, on the basis of the prevailing accessory mineral or minerals—mica (biotite or muscovite), hornblende, and augite. Thus a granite containing muscovite (white mica) is termed a muscovite granite; one containing biotite (black mica) a biotite granite (granitite); one containing both a muscovite-biotite granite; one containing hornblende a hornblende granite; one containing hornblende and biotite a hornblende-biotite granite, etc. The name unakite is given to a granite with pink feldspars and rich in epidote that occurs in the Unaka Mountains of eastern Tennessee and western North Carolina and is known in two localities in the Blue Ridge of Virginia.

The varieties of granite occurring in the region covered by this bulletin are chiefly biotite, muscovite, and muscovite-biotite granites, and hence are referred to as mica granites. The biotite granites greatly predominate.

A general classificatory scheme of the granites occurring within this region is not given here; those of each State, however, are classified in the respective chapters.

STRUCTURE.

Under the term structure are included all divisional planes that traverse granite, whether of microscopic or macroscopic proportions, such as rift and grain, joints, faults, etc.

RIFT AND GRAIN.

The rift and grain in granite are structures of considerable economic importance, for they lessen the cost of quarrying, when well developed, by facilitating the operations of the workmen. They are obscure microscopic foliations, inclined at an angle of about 90° to each other, along which the rock splits more easily than in other directions. The rock splits easier in the direction of rift than of grain. These structures may not be visible to the ordinary observer, but are easily detected by an experienced stonecutter.

In the study of the hornblende-biotite granite of Cape Ann, Mass., Tarr [a] found that rift consisted of minute fractures and faults crossing the feldspar and quartz alike, although some go around the quartz grains rather than through them. Whittle [b] details similar observations for the granite quarried at Redstone, N. H., and remarks that notwithstanding the pronounced rift and grain of this granite it stood a compression test of 22,370 pounds to the square inch and was not appreciably weakened by the microscopic fractures. Dale [c] later corroborated Whittle's observation on this granite.

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[a] Tarr, R. S., The phenomena of rifting in granite: Am. Jour. Sci., 3d ser., vol. 41, 1891, pp. 267-272.

[b] Whittle, C. L., Rifting and grain in granite: Eng. and Min. Jour., vol. 70, 1900, p. 161.

[c] Dale, T. N., The granites of Maine: Bull U. S. Geol. Survey No. 313, 1907, p. 27.

Rift and grain data were collected by Dale[a] at 53 quarries of Maine granites; at 29 of these the rift was vertical, and at 24 it was horizontal and the grain was vertical. According to Dale the courses of the rift and grain are distributed as follows:

Courses of rift in Maine granites.

	Number of quarries.
N. 10° W.-N. 10° E	6
N. 22°-50° W	5
N. 30°-77° E	3
N. 60°-70° W	9
East-west to N. 85° E. and N. 80° W	6

Courses of grain in Maine granites.

	Number of quarries.
North-south	2
N. 20°-25° W	2
N. 45°-75° E	4
N. 45°-72° W	6
East-west to N. 80° E	10

From these observations Dale says: "It appears, therefore, that when rift or grain is vertical the east-west and west-northwest to northwest courses are the most common, and next the north and east-northeast to northeast courses."[b]

The rift and grain are not always pronounced in the granites of the southeastern Atlantic States, but, as a rule, they are sufficiently developed to facilitate quarrying operations. In some places they are but poorly defined, but nowhere, so far as the writer is aware, are they entirely absent.

From the numerous tests it seems that rift, in some cases at least, influences the crushing strength of the granite. That is to say, the ultimate strength of granite is greater when pressure is applied at right angles to the rift than when applied parallel to it.[c]

JOINTS.

OCCURRENCE.

Joints in rocks of commercial grade are of considerable economic importance, for their character and abundance largely determine the size of blocks that may be quarried. Where not too closely spaced and not discolored by sap they greatly benefit the quarries; but where too abundant and closely spaced and where they intersect at sharp and obtuse angles, they are decidedly harmful, as the extraction of dimension stone is rendered impossible.

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[a] Dale, T. N., The granites of Maine: Bull. U. S. Geol. Survey No. 313, 1907, pp. 28, 29.

[b] Idem, p. 29.

[c] See results of tests of materials by J. W. Reilly, as quoted by Dale, T. N., The granites of Maine: Bull. U. S. Geol. Survey No. 313, 1907, p. 29.

Two systems of joints, a vertical set and a horizontal set, and, in many places, a third, diagonal system intersect the granites treated in this bulletin. These may be widely spaced or closely spaced. Usually the spacing is sufficiently wide to admit of dimension stone being quarried. Motion in the granite masses since the formation of the joints is evident from the polished and striated surfaces of the joints.

VERTICAL JOINTS.

Considerable variation is shown in the development of the vertical joints. In most places they are conspicuously developed; in others, especially in the granite domes of Georgia (Stone Mountain and similar domes in the Lithonia area) and North Carolina, they are much less abundant. Visible jointing is not apparent in the Mount Airy, N. C., quarries.

Observations in the quarries of the southeastern Atlantic States show two principal sets of vertical joints, lying in the northeast and the northwest quadrants; in many quarries there is also minor jointing in two other directions, east-west and north-south. In some localities the joints are irregular with respect to continuity, strike, and dip. Joints indicating a considerable degree of curvature are noted in a few localities and are described in some detail in the chapters on the individual States.

HORIZONTAL JOINTS.

Joints dividing the granite into "sheets" are usually strongly developed in the granites of the Southern States. Such joints are usually parallel to the granite surface. In flat-surface exposures they approach a horizontal position; in gently arched exposures they have approximately the same degree of curvature as that of the granite surface; and in the steep domes they are correspondingly steep, observing parallelism with the doming surface.

Horizontal joints are usually more conspicuous at and near the surface, and become less prominent below. They apparently disappear in most quarries that are opened to any considerable depth. Ordinarily the joint planes separate the rock into thinner sheets at or near the surface and into thicker sheets at greater depth. The thickness of the sheets shows considerable variation, ranging from several inches to 6 feet or more.

There is a great diversity of opinion among geologists as to the cause of these joints, some regarding them as one of the effects of external temperature changes (solar heat), and some believing them to be due chiefly to compressive or torsional strain.[a]

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[a] See a recent review of the literature on "sheeting" by Dale in Bull. U. S. Geol. Survey No. 313, 1907, pp. 30-38.

Joint structure, vertical and horizontal, in the granites of the Southern States is shown in Plates II, X, and XI.

SLICKENSIDES.

In most of the granite quarries where the joint structure is at all well developed the joints show smooth, more or less polished and striated surfaces, indicating considerable movement in the granite masses since the formation of the joints. A very thin coating or veneer of a reddish and yellow to greenish-yellow mineral substance is developed on many of the joint surfaces. This is an alteration product, derived from certain original minerals of the fresh granite and resulting from the rubbing together of the two sides along the plane.

ROCK VARIATIONS.

Under the term "rock variations" are grouped those variations from typical granite that are due to injection, infiltration, inclusion, segregation, etc.[a]

DIKES.

The dikes in the southern granites are divisible on a chemical basis into two groups—(1) dikes of acidic composition, including very fine grained, nearly mica-free granite (aplite), and very coarse grained granite (pegmatite); and (2) dikes of basic composition, including diabase and amphibolite.

ACIDIC DIKES.

Granite-aplite.—Granite-aplite differs from normal granite in its greater fineness of grain, in containing very little or no mica, and in its very light, nearly white color. Dikes of it are only occasionally seen in the granites of the Southern States. They have been noted by the writer in the Richmond, Va., granite area;[b] the Raleigh, N. C., granite area;[c] the Columbia and Lexington granite areas and the Anderson quarry in Fairfield County, S. C., and the Stone Mountain, Ga., granite area,[d] and are plainly of an intrusive nature. They occur both as separate dikes in the granite and associated with the pegmatite dikes as banded aplite-pegmatite dikes. They are usually less than 6 inches thick, and in color they are very light, except those of the Columbia, S. C., area which are decidedly reddish brown. They are very fine grained in texture, the mineral particles not being distinguishable, as a rule, with the unaided eye. For a detailed description of the individual occurrences see pages 85, 120, 178–179.

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[a] Dale, T. N., op. cit., p. 42.

[b] Bull. Geol. Soc. America, vol. 17, 1906, p. 530.

[c] Bull. North Carolina Geol. Survey No. 2, 1906, pp. 33, 180. Jour. Geology, vol. 12, 1904, pp. 403–404.

[d] Jour. Geology, vol. 10, 1902, pp. 186–190. Bull. Georgia Geol. Survey No. 9-A, 1904, pp. 275–276.

Pegmatite.—Pegmatites are present, usually, in great numbers in the granites of the Southern States, and some of them attain considerable size. (See Pl. III.) They are abundant in some quarries and entirely absent in others. Only here and there are they so numerous as to interfere seriously with quarrying operations, the most noteworthy example being at the city quarries of biotite granite at Raleigh, N. C., where hardly a block of any size can be quarried that is entirely free from pegmatite dikes; this is illustrated in the state building in Raleigh, which is constructed of this stone.

The pegmatites are granitic in their mineralogy, consisting of very coarse crystallizations of feldspar and quartz with less mica (muscovite or biotite, rarely both). As a rule, these minerals are not uniformly distributed through all parts of the dikes, but are scattered very irregularly, first one and then the other predominating. The pegmatites associated directly with the granites in the quarries are as a rule remarkably free from unusual or rare minerals. Garnet is commonly present, and in the dark-blue granite quarries of Fredericksburg, Va., massive granular magnetite is associated with the garnet. In the pegmatites of the granite quarries at Stone Mountain, Ga., both tourmaline and garnet occur. Black tourmaline is observed in some of the pegmatites of the Johnson quarry near Pacolet, S. C.

Many of the larger pegmatite dikes penetrating the crystalline rocks of the southern region contain unusual minerals. This is especially true of parts of the crystalline area in Virginia and the Carolinas.[a]

The potash feldspars, orthoclase and microcline, are the dominant feldspar species in the pegmatites, though an acidic plagioclase is usually present. The commonest colors are white and reddish pink, with pronounced green in some of the Virginia dikes. Twinning on the Carlsbad law is common and good cleavage development is a marked characteristic. The quartz is usually of the light and the dark smoky varieties, which contrast sharply with the feldspar. Of the micas, both muscovite and biotite occur in places associated in the same dike, but usually separated, with biotite probably more common than muscovite. The biotite is usually present in large, stout, platy forms, at some places irregularly distributed between the feldspar and quartz, at others distributed along a central axis in the dike. The micas are of the usual kinds and are in no way noteworthy.

As a rule, the pegmatites are more irregular in width than the aplites, though here and there they extend for considerable distances with remarkable regularity. Some dikes are very extensive, are apparently deep seated, and are of aqueo-igneous origin. Others are small, are surrounded entirely by the granite, and probably denote true veins of segregation. Locally they conform to the joint courses, and in some of the gneisses they are insinuated in the planes of the schistosity, but at many places they apparently do not conform to any definite or fixed direction but cut the granite at random and at all angles.

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[a] Watson, T. L., Mineral resources of Virginia, 1907, pp. 276-285, references cited. Kunz, G. F., Bull. North Carolina Geol. Survey No. 12, 1907, pp. 25-28. Graton, L. C., and Lindgren, Waldemar, Bull. U. S. Geol. Survey No. 293, 1906, pp. 20-22, 35-40, 42-43, 53-54, 57. Keith, A., Cranberry folio (No. 90), 1903; Mount Mitchell folio (No. 124), 1905; Pisgah folio (No. 147), 1907, Geol. Atlas U. S., U. S. Geol. Survey.

The pegmatites in some localities are of different periods of formation. In the Richmond (Va.) granite area[a] there are three granites (including the granite gneiss), representing as many periods of intrusion, each of which was accompanied by the formation of pegmatites. The structural relations of the pegmatites to the granites in the Richmond area are shown in figures 4, 5, and 7.

Faulting has been observed in the pegmatites at the Donald quarry (fig. 8) in the Richmond area; in the large granite exposures on the Adams place near Clover, in York County, S. C., and at the following quarries in North Carolina: The Raleigh City quarry; the Carrigan quarry, 3 miles northeast of Mooresville, Iredell County; and the Walker quarry, 1½ miles southeast of Ridge Summit station, Guilford County. The displacement amounts to only a few inches, and in each locality the faulting occurs at the point of intersection of one pegmatite by another.

Granite.—The granite dikes differ from those of aplite and pegmatite in being formed of fine or medium grained granite, and they correspond in composition and otherwise to the normal granite. They vary in width from a few inches to 40 feet as an extreme, near Camak, Ga.; usually they vary from 4 to 12 inches. They are dark gray in color and fine to medium grained in texture, and are composed of potash (orthoclase and microcline) and soda-lime (oligoclase) feldspars, quartz, and biotite as the essential minerals, together with the usual microscopic accessory minerals.

Granite dikes are typically developed in some of the granite quarries of Maryland, Virginia, North Carolina, and Georgia. The more important localities are the following: Maryland, Weber's quarry at Ellicott City, and the railroad cut at Dorsey Run; Virginia, Davis and Cartright quarries, near Fredericksburg; North Carolina, Greystone quarries in Vance County, and Mount Mourne in Iredell County; Georgia, Sparta quarries in Hancock County, near Camak, and at Holders Mill in Warren County, and the Odessa quarry in Meriwether County.

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[a] Watson, T. L., Lithological characters of the Virginia granites: Bull. Geol. Soc. America, vol. 17, 1906, pp. 536–539.

A chemical analysis of specimens collected from a 40-foot dike of fine-grained dark-gray granite cutting porphyritic granite gneiss near Camak, Warren County, Ga., yielded the following results:

Analysis of granite dike near Camak, Ga.

[T. L. Watson, analyst.]

Silica (SiO_2)	68.76
Alumina (Al_2O_3)	16.80
Iron oxide (Fe_2O_3)	.99
Lime (CaO)	2.72
Magnesia (MgO)	1.00
Soda (Na_2O)	4.82
Potash (K_2O)	3.70
Ignition	.29

A chemical analysis of selected specimens from different parts of light-colored granite dikes penetrating massive granite and gneiss in the railroad cut at Dorsey Run station, Howard County, Md., gave the following results.[a]

Analysis of granite dikes at Dorsey Run, Md.

[W. F. Hillebrand, analyst.]

Silica (SiO_2)	70.45
Alumina (Al_2O_3)	15.98
Ferric oxide (Fe_2O_3)	.75
Ferrous oxide (FeO)	1.84
Magnesia (MgO)	.77
Lime (CaO)	2.60
Soda (Na_2O)	3.83
Potash (K_2O)	3.59
Water (H_2O)	.43
Lithia (Li_2O)	Trace.
	100.26

BASIC DIKES.

Dikes of basic igneous rocks, principally diabase or its altered form, penetrate the granite in many localities, especially in North Carolina and to a smaller extent in South Carolina and Georgia. In several of the North Carolina granite quarries as many as half a dozen dikes were observed in a single quarry. The dikes are rarely 50 feet across and usually are less than 4 feet.

Lithologically two types are indicated. The principal type is usually an unaltered massive rock, thin sections of which display the mineralogy and texture of diabase. The pyroxene in this type may be considerably altered in some of the dikes, and in hand specimens the rock has a pronounced greenish color, from the amount of chlorite present. The other and less abundant type is more or less completely thinly schistose, is largely composed of hornblende with some feldspar and quartz, and may contain much pyrite; it is, therefore, a typical amphibolite.

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[a] Keyes, C. R., Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 722, 723.

The structural relations of the dikes to each other and to the inclosing granites clearly indicate at least two different periods of formation. In some places both the inclosing granite and the dike are schistose in structure, indicating intrusion of the dike material into the granite prior to the period of dynamic disturbance that induced schistosity in the two rocks. These dikes are regarded as pre-Newark in age. In many localities, however, the dike rock is entirely massive and the granite schistose in structure, indicating that the dike material was intruded into the granite after the period of dynamic disturbance. A few of these dikes have been traced from the granites into the Triassic sandstones along the eastern border of the Piedmont region, and are therefore of Mesozoic age.

In the North Carolina quarries conditions are more favorable for studying the relations of the basic dikes to joint structure than in the granite areas of the other Southern States. Of 71 dikes measured in the North Carolina quarries, 37 lie in the northwest quadrant and 22 in the northeast, 13 have a north-south course and 2 an east-west one. Likewise, measurements of 136 joints show that 44 lie in the northwest quadrant and 57 in the northeast, and that the remainder have north-south and east-west courses. Furthermore, in nearly every quarry exposing basic dikes the strike of the dikes and that of one set of joints were coincident, probably indicating that for the North Carolina areas the jointing has exercised some influence on the direction of the dikes.[a]

QUARTZ VEINS.

Quartz veins of large dimensions are numerous over the crystalline region of the Southern States, but they are rather exceptional in the granite quarries of that region. In a number of the North Carolina quarries and in the Port Deposit quarries, Maryland, quartz veins of small dimensions have been observed. These commonly occur in those quarries in North Carolina where pegmatite dikes are abundant. The quartz veins are more or less closely associated with the pegmatites, and do not exceed a few inches in width. The quartz composing the veins is of the usual clear vitreous variety.

In the Columbia quarries of Fluvanna and Goochland counties, Va., quartz veins up to 2 feet wide are abundant. They are very irregular in thickness and inclose thin seams of chlorite (from biotite) along central and contact positions.

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[a] Watson, T. L., and Laney, F. B., with the collaboration of Merrill, G. P., The building and ornamental stones of North Carolina: Bull. North Carolina Geol. Survey No. 2, 1906, pp. 184-187.

BASIC SEGREGATIONS (KNOTS).

In many of the quarries the granite contains dark-gray or black basic segregations (knots) of fine-grained texture, formed from the cooling magma. The segregations are finer grained and of darker color than the granite in which they occur. Thin sections show the same essential minerals as in the granite but in different proportions, the dark ferromagnesian minerals, biotite and hornblende, or both, in large excess, with less quartz and feldspar. Some segregations are so fine grained and so very dark in color that it requires very close naked-eye examination to detect other minerals than the ferromagnesian silicates. In outline the knots are usually circular or elliptical, much-elongated masses, ranging in diameter from less than an inch to several feet.

The distribution of the segregations in the granite is subject to considerable variation, but is always irregular and without definite order or orientation. From some quarries they are entirely absent, in others they are developed only locally, and in others still they are so abundant as to disfigure the rock and exclude it from use for the higher grades of work. The segregations appear to be most abundantly developed in the hornblende-biotite granites, especially those of the Falls Church area in Virginia and the Mecklenburg County areas in North Carolina, where many of them are large.

The following table shows the percentage of silica in and the specific gravity of basic segregations in granite.[a]

Silica percentage and specific gravity of knots.

Locality.	Silica.		Specific gravity.	
	Granite.	Segregation.	Granite.	Segregation.
Port Deposit, Maryland	73.70	62.20	2.69	2.83
Peterhead, Scotland	73.70	64.39	2.69	2.73
Shap Fell, Westmoreland	69.78	56.95	2.69	2.77
Gready, Cornwall	69.64	65.01	2.72	2.73
Barr-Andlan, Alsace	68.97	57.89	2.68	2.78

[a] Bascom, F., Maryland Geol. Survey, Cecil County, Md., 1902, p. 112.

INCLUSIONS.

Inclusions are irregular fragments of country rock of all sizes and shapes that have been torn off and incorporated in the granite during its intrusion. They not uncommonly closely resemble the basic segregations (knots) described above, but can usually be distinguished from them by their different microscopic structure. Inclusions of this kind occur here and there in the granites of the Southern States, but are especially well marked in the granites of the Woodstock and Sykesville districts, Maryland.[a] At Woodstock the inclusions are chiefly irregular blocks of gneiss, 6 to 8 or even 10 feet in size. Their outlines are sharply defined against the granite which contains them. In the Sykesville district the inclusions comprise fragments of all sizes and shapes, of limestone, soapstone, pyroxenite, vein quartz, and hornblende and biotite gneisses.[a]

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[a] Keyes, C. R., Origin and relations of central Maryland granites: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 723-724, 726-729.

In the Richmond-Fredericksburg area, Virginia, the dark-blue gray granite in some of the quarries contains inclusions of the massive light-gray granite and of the gneiss. The foliation of the gneiss inclusions incorporated in the granite at the McGowan quarry is entirely preserved (Pl. XII, *B*).

In the Carolinas and Georgia granite areas inclusions have been noted but are less numerous and, with several exceptions, are not so pronounced in character as in the Maryland and Virginia areas.

MINERALS ON JOINT FACES.

The surfaces of the joint planes in the granites of the region discussed in this bulletin are at many places coated with minerals which occur but sparsely or not at all in the granite. Generally the coat consists of the barest film or veneer of a yellow, yellowish-green, or reddish mineral substance, which, as a rule, is probably damourite, in some places epidote, or a mixture of the two, being a dynamic alteration product resulting from movement in the granite mass. At the old state (Middendorf) quarries, near Granite station, Virginia, the joint faces are coated here and there with radiating tufts or clusters of stilbite, a hydrous silicate of alumina, lime, and soda. Joints in some of the North Carolina quarries are coated with pyrite, which has probably resulted from infiltrations along the joint courses.

At Stone Mountain, Ga., the minerals uranophane[b] ($CaO, 2UO_3, 2SiO_2+6H_2O$) and hyalite ($SiO_2. nH_2O$, opal) occur as incrustations, coating the faces of many of the joints that cut the light-gray biotite-bearing muscovite granite. The uranophane is of yellow color and the coating of it does not exceed one-eighth to one-sixteenth inch in thickness, and is usually less. It is tipped or coated with clear, colorless, and transparent droplike globules of hyalite. The two minerals are so intimately associated that it is almost impossible to effect a complete separation of them.

A chemical analysis of the uranophane by Packard gave:

Analysis of uranophane from Stone Mountain, Ga.

SiO_2	18.55
$U(UO_4)_2$	47.18
$(UO_2)_2$, Fe_2O_3, P_2O_5	4.95
Al_2O_3	6.33
CaO	6.64
MgO	1.98
H_2O (ignition)	13.28
	98.91

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[a] Keyes, C. R., Origin and relations of central Maryland granites: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 726-729.

[b] Watson, T. L., On the occurrence of uranophane in Georgia: Am. Jour. Sci., 4th ser., vol. 13, 1902, pp. 464-466.

In Maryland G. H. Williams[a] reported the following minerals on the surfaces of the joints that intersect the gneiss in the large quarries on Jones Falls and Gwynns Falls, at the northern and western limits of the city of Baltimore: Haydenite (chabazite), laumontite, harmotome (or phillipsite?), stilbite, beaumontite (heulandite), siderite, pyrite, barite, halloysite, epidote, garnet, and tourmaline.

WEATHERING.

When exposed for a sufficient length of time to the atmosphere all rocks undergo decay, the siliceous crystalline rocks like granite being converted superficially into a loose, incoherent mixture of ferruginous sand and clay. As a result of this process of degeneration, or weathering as it is commonly called, the rocks of the Southern States are very generally covered with a mantle of variable thickness of residual materials. Frequently the loose, decayed rock mantle must be removed before quarrying can be commenced. (See Pl. V, *B*.)

Notwithstanding this widespread decay of the rocks over the southern region, exposures of the granite are numerous, presenting a variety of form. They appear chiefly as flat-surfaced masses of variable extent, as large and small bowlders either lying on the surface or partly buried in the residual material (Pls. XVI, *B;* XVII, *A;* XXIII, *A*, *B*), as dome-shaped masses of large and small dimensions having steep or gentle slopes (Pls. XIV, *B;* XVII, *B;* XXV, *A*, *B;* XXVII, *A*), and as low or high ledges along stream courses (Pls. X, XI).

Much has been written recently on the decay (weathering) of granite, but it will suffice here to give only some of the more important references to the literature:

JULIEN, ALEXIS A. The durability of building stones in New York City: Tenth Census, vol. 10, 1884, pp. 370, 371; A study of the New York obelisk as a decayed bowlder, Annals New York Acad. Sci., vol. 8, 1893, pp. 93–166.

KEYES, C. R. The origin and relations of central Maryland granites: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 725; Surface disintegration of granitic masses: Proc. Iowa Acad. Sci., vol. 1, pt. 3, 1893, pp. 22–24; Secular decay of granitic rocks, Proc. Iowa Acad. Sci., vol. 2, 1895, pp. 27–31.

MERRILL, GEORGE P. Stones for building and decoration, 3d ed., New York, 1903, pp. 418–446; The physical, chemical, and economic properties of building stone: Maryland Geol. Survey, vol. 2, 1898, pp. 92–94; A treatise on rocks, rock weathering, and soils, 2d ed., New York, 1906, pp. 185–195, 231–232; Disintegration of the granitic rocks of the District of Columbia: Bull. Geol. Soc. America, vol. 6, 1895, pp. 321–332.

WATSON, THOMAS L. A preliminary report on a part of the granites and gneisses of Georgia: Bull. Georgia Geol. Survey No. 9–A, 1902, pp. 298–348; Weathering of the granitic rocks of Georgia: Bull. Geol. Soc. America, vol. 12, 1901, pp. 93–108.

The views shown in Plates V, *A*, *B*, and XVII, *A*, indicate the mode of weathering usually characteristic of granites, particularly where traversed by joints. Joints are easy lines for the percolation of surface waters, which move downward along the vertical joints and laterally along the horizontal joints, producing disintegration and decomposition of the granite, extending inward from the joint surfaces. The incipient stage of granite weathering may be observed in any exposed granite ledge by the whiteness and opacity of the feldspars, the rock having undergone kaolinization from hydration. The amount of water increases rapidly as decomposition advances.

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[a] Notes on the minerals occurring in the neighborhood of Baltimore, 1887, 17 pages. (Quoted by Mathews, E. B., op. cit., p. 164.)

In the more advanced stages of weathering, solution and oxidation, promoted through atmospheric waters, become dominant factors in the process. As a result of these changes, disintegration and decomposition, the granite is finally reduced to sand and clay, more or less discolored by iron oxides set free through decomposition of iron-bearing minerals, such as biotite, hornblende, etc.

The weathering of siliceous crystalline rocks like granite involves the following chemical changes: A loss in silica, a greater proportional loss in lime, magnesia, and the alkalies (soda and potash), and a proportional increase in the amounts of alumina and sometimes of iron oxide.[a] In extreme cases the total loss may be nearly 75 per cent of the entire rock mass,[b] though it rarely amounts to more than 60 per cent. Careful study of District of Columbia granites by Merrill and of Georgia granites by the writer shows the total losses produced by chemical decay (decomposition), calculated from chemical analyses of the fresh and corresponding decayed rock, to be as follows:

Total percentage losses accompanying the decay of granites.

DISTRICT OF COLUMBIA.[c]	
Foliated gray micaceous granite	13.79
GEORGIA.[d]	
Light-gray biotite granite, Swift & Wilson quarry, Elberton	7.92
Blue-gray biotite granite, Lexington Blue Granite quarry, Lexington	14.56
Porphyritic biotite granite, Heggie Rock, Columbia County	15.84
Biotite granite gneiss, Crossley quarry, Lithonia	26.69
Porphyritic biotite granite gneiss, Brinkley Place, Camak	34.04
Porphyritic biotite granite, McCollum quarry, Coweta County	35.07
Biotite granite, Cole quarry, Newnan	38.45
Biotite granite, Coggins quarry, Oglesby	44.72
Biotite granite, Greenville Granite Company's quarry, Greenville	71.84

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[a] Merrill, G. P., A treatise on rocks, rock weathering, and soils, 2d ed., New York, 1906, p. 220.

[b] Watson, T. L., A preliminary report on a part of the granites and gneisses of Georgia: Bull. Geol. Survey Georgia No. 9-A, 1902, pp. 312-317.

[c] Merrill, G. P., Bull. Geol. Soc. America, vol. 6, 1895, pp. 321-332.

[d] Watson, T. L., Bull. Geol. Survey Georgia No. 9-A, 1902, p. 333.

It should be remarked that decay was not equally advanced, chemically, in these granites. However, in each one the decayed product represented loose material. Those granites showing the smallest percentage loss listed in the table crumbled largely through physical changes (disintegration). The most advanced stage in chemical decay (decomposition) is represented in the granite from the Greenville Granite Company's quarry, Greenville, Ga.

An interesting form of weathering very frequently observed in the southern granites is illustrated in Plate V, *A*, *B*, which shows granite bowlders consisting peripherally of concentric shells, which break off one after another in passing from the surface toward the center. This form of weathering has resulted from the more rapid decay on the edges and corners than on the flat sides of the jointed granite blocks, the blocks being gradually rounded and formed into bowlder-like masses of varying size.

DISTRIBUTION OF THE GRANITIC ROCKS.

Reference to the map (fig. 1) will show that the region discussed includes the southern half of the northern Appalachians and all of the southern Appalachians. The boundary between the northern and southern Appalachians[a] is a line drawn from the most easterly point of Kentucky southeastward across Virginia and North Carolina to Cape Fear, on the Atlantic. The two divisions show decided differences in the forms of relief and in the drainage.

The region is divided into three well-defined physiographic provinces, which are intimately related to its geologic structure. These are, named in order from southeast to northwest, (*a*) the Coastal Plain; (*b*) the Piedmont Plateau; and (*c*) the Appalachian Mountains. The three provinces observe a general parallelism with each other and with the present coast line, trending northeast and southwest.

COASTAL PLAIN.

The easternmost of the provinces, known as the Coastal Plain, comprises the area between the Atlantic Ocean and a line passing in a general southwesterly direction from a point near New York City to Columbus, Ga., through or near Trenton, Philadelphia, Baltimore, Washington, Richmond, Petersburg, Raleigh, Columbia, Augusta, Macon, and Columbus. There is a general widening of the Coastal Plain region to the southwest from about 100 miles in northern Maryland to 200 miles or more in Georgia. It is characterized as a low, flat-lying area, whose elevation gradually increases from sea level at the coastal border to 400 or 500 feet at its western edge. It is composed of loose and partly consolidated sediments, chiefly sands, clays, and marls, which preserve a gentle seaward dip.

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[a] Hayes, C. W., Physiography of the United States; The southern Appalachians: Nat. Geog. Mon., No. 10, New York, 1896, p. 305.

No granites are found within the Coastal Plain except in small areas of a few inliers of the Piedmont crystalline rocks, which are exposed mainly along the stream courses near its western margin by stripping off the veneer of loose sediments. The inliers are composed, either partly or wholly, of granite, and quarries are opened in a few of these areas in Maryland, Virginia, the Carolinas, and Georgia.

PIEDMONT PLATEAU.

The middle province, known as the Piedmont Plateau, is named from its position along the eastern foot of the Appalachian ranges. It is bordered by the Coastal Plain on the east and extends to and along the southeastern base of the Appalachian Mountains. It averages about 50 miles in width in Maryland but broadens toward the southwest until it reaches a maximum of approximately 125 miles in North Carolina; it narrows through South Carolina and Georgia, and finally passes beneath the Paleozoic and Coastal Plain sediments in central Alabama. (See fig. 2.)

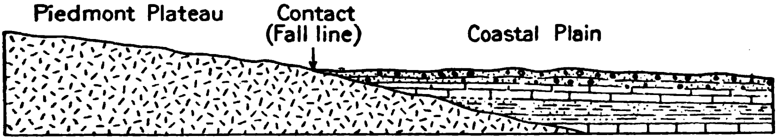

FIGURE 2.—Generalized section showing relations of the Coastal Plain formations to the Piedmont Plateau crystalline rocks.

The surface of the Piedmont Plateau shows a gentle eastward slope from an altitude of 1,000 to 1,200 feet at the western edge to one of 400 to 500 feet along the eastern margin. Geologically the region is formed of a complex of highly metamorphosed sedimentary and igneous rocks of Paleozoic and pre-Paleozoic age, largely concealed beneath a cover of residual material due to decay. Because of the thick mantle of loose residual material exposures of the fresh rock are less numerous than they are farther north.

The Piedmont Plateau differs markedly from the Coastal Plain in the nature and origin of its surface features and in the age, kinds, and structure of its rocks. Its surface is not a smooth plain but is broadly undulating or rolling, and the streams cross it in rather deep and narrow channels. Less reduced areas of the harder rocks, rising several hundred feet above the upland surface of the plateau, are not uncommon over the region. Toward the eastern margin the hills rise but little above the plateau surface but as the western margin is approached they rise higher and higher above the general surface until, in North Carolina, a few of them reach elevations of several thousand feet. Through the Carolinas and a part of Georgia the western limit of the plateau is irregular and is marked by the change from the general sloping surface to the steep slopes of the Blue Ridge and its outliers. Farther south in Georgia and Alabama its western limit is less well defined, owing to the fact that the surface of the mountain belt has been worn down nearly to that of the plateau. The transition from the rocks of the plateau along its northwest margin to the metamorphosed strata of the mountain province is less distinctly marked and not so abrupt as the change from the Coastal Plain sediments.

The rocks of the Piedmont Plateau are wholly crystalline and are derived in part from original sediments and in part from original igneous masses. They include chiefly crystalline gneisses and schists associated with crystalline limestones, quartzites, and phyllites, intruded by granitic and gabbroitic rocks and more basic rocks (peridotites and pyroxenites). The gabbroitic rocks include a wide range of types, many of which are admirably suited for structural purposes and have been or are being quarried in places for building and ornamental stone. The abundance, variety, and general excellence of the granites make them the most important for use in commercial work. The entire production of granite from the southeastern Atlantic States is from the Piedmont province.

Over parts of the Piedmont region in Maryland, Virginia, and North Carolina Newark (Triassic) sediments, including sandstones, conglomerates, and shales, have been deposited. These sediments are broken by faults and are penetrated by large and small dikes of diabase, which are quarried in places, the product being known to the trade as "black granite."

As a rule, the original features of the rocks composing the Piedmont Plateau have been largely changed by profound metamorphism since the formation of the rocks. The principal changes have been recrystallization and textural modification. The most marked textural change has been the development of pronounced foliation or schistosity in most of the rock types. The foliation or schistosity of the rocks is in general coincident with the trend of the province, northeast and southwest, but varies in dip. It is present in both the sedimentary and the igneous rocks. In the former the foliation is so strongly developed that it largely obscures the original bedding planes, and frequently renders their determination impossible. In the igneous rocks foliation is in places so pronounced as entirely to obscure the original appearance of the rock; in other places all gradations between the unaltered massive rock and the foliated types may be traced.

The streams crossing the Piedmont Plateau have rapid currents as far as its eastern border, but even the largest rivers are not navigable. Several of the easternmost areas, however, in Maryland

and Virginia more especially, lie adjacent to tide water, where shipment by water is possible over the larger navigable streams which cross the Coastal Plain region. But, notwithstanding the favorable location of these areas, practically all the quarried material in the Piedmont region is shipped by rail, largely because of the excellent transportation facilities afforded by the numerous lines of railway which traverse nearly all parts of the region.

Granites are extensively worked at the following localities in the Piedmont Plateau south of Pennsylvania: At Port Deposit, Guilford, and Woodstock, in Maryland; near Fredericksburg, Richmond, and Petersburg, in Virginia; near Mount Airy, Salisbury, and Greystone, in North Carolina; near Beverly, Columbia, Heath Springs, Lexington, and Winnsboro, in South Carolina; at Stone Mountain, Lithonia, Oglesby, and Sparta, in Georgia; and in numerous minor areas. Plates I, VII, XIII, XXI, and XXIV show the location, by States, of the granite quarries from Pennsylvania to Alabama.

APPALACHIAN MOUNTAINS.

The Appalachian Mountains[a] region is bordered by the Piedmont Plateau on the southeast, and extends northwestward to the eastern limits of the greater Appalachian Valley, comprising a mountainous belt of variable width. It extends southwestward from the high land of South Mountain in Pennsylvania, through Maryland, Virginia, and western North Carolina, and terminates in northern Georgia and eastern Alabama. Throughout their extent the eastern members of this belt are generally known as the Blue Ridge. Maximum heights of 6,600 and 6,700 feet are reached in western North Carolina, and there is a gradual lowering toward Alabama and Virginia. The mountain belt widens to its greatest width of about 70 miles in western North Carolina. Its southeastern edge is marked by the southeastern front of the Blue Ridge, and the northwestern edge by the somewhat higher Unaka Range. It merges into the Blue Ridge toward the Virginia line, and terminates southwestward in northern Georgia. Between the two ranges the area is occupied by numerous groups of irregular mountain masses which rise to elevations of 4,000 to 6,700 feet. The mountains are rugged and deeply dissected.

Roanoke River and the major streams north of it, like the James, Potomac, and Susquehanna, rise west of the Blue Ridge and flow southeastward across it into the Atlantic Ocean. New River, which gathers its waters in the Blue Ridge region of northwestern North

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[a] Hayes, C. W., Physiography of the United States: The southern Appalachians, 1896, pp. 305-336.

Willis, Bailey, Physiography of the United States: The northern Appalachians, 1896, pp. 169-202.

Powell, J. W., Physiography of the United States: Physiographic regions of the United States, 1896, pp. 65-100.

Keith, Arthur, The Appalachian mountains and valleys: Science, n. ser.. vol. 25, 1907, pp. 865-867.

Carolina, follows a northwestward course across the greater valley and the plateau into the Ohio. From Roanoke River southwestward the crest of the Blue Ridge marks the divide between the Atlantic and the Gulf drainage. The southeastern slopes of the Blue Ridge are usually steep, in contrast with the more gentle northwestern slopes.

Igneous rocks, comprising acidic and basic volcanic rocks and granites of pre-Cambrian (Algonkian) age, make up a considerable part of the mountain belt (Blue Ridge) in Maryland and Virginia.[a] The granites are closely associated with and cut the volcanic rocks, forming long, narrow belts, which vary in width up to 6 miles. The granites vary in texture and composition and, as a rule, are greatly changed by metamorphism, many of them resembling schists.

Keith's studies [b] of the region farther southwest, in the western Carolina portion of the belt, disclose the fact that the main mass of the mountains is composed of gneisses, through which have been injected igneous rocks of various descriptions, mainly granites. According to Keith, these rocks are, for the most part, Archean, but include some also of Algonkian age. The granites, which are very abundant over the Carolina portion of the mountain belt, vary in texture and color and show marked evidences of metamorphic changes. They are described in some detail on pages 153-161.

Over many parts of the mountain belt, but more especially over the western Carolina portion, granites of excellent quality are to be found. These, however, have nowhere been developed, except that here and there a quarry has been opened to supply a very local trade. The remoteness of many of them from lines of transportation, the ruggedness of the region in general, and the practical lack of demand for stone of this kind within the belt have been the principal factors against development.

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[a] Keith, Arthur, Geology of the Catoctin belt: Fourteenth Ann. Rept. U. S. Geol. Survey, 1894, pp. 285-395.

[b] Keith, Arthur, Cranberry folio (No. 90), 1903; Asheville folio (No. 116), 1904; Mount Mitchell folio (No. 124), 1905; Nantahala folio (No. 143), 1907; Pisgah folio (No. 147), 1907: Geol. Atlas U. S., U. S. Geol. Survey.

CHAPTER II.

THE GRANITES OF MARYLAND.

THE MARYLAND PIEDMONT REGION.

The Maryland portion of the Piedmont province embraces a small trapezoidal area which is bounded by the fall line on the east, Catoctin Mountain on the west, Potomac River on the south, and the southern boundary of Pennsylvania on the north.[a] According to Abbe, its topography embraces features of three different classes—the broad, rolling upland surface, the valleys carved in the upland, and the residual masses which rise above the upland. It is divided near its central portion by an area of high land known as Parrs Ridge into an eastern and western district, each of which has its own peculiar characters. It has an approximate total area of 2,500 square miles, including Cecil, Harford, Baltimore, Howard, and Montgomery, and parts of Frederick and Carroll counties. Parrs Ridge forms the divide between the streams flowing eastward across the Piedmont into Chesapeake Bay direct, and those which flow westward to the Monocacy and thence to the bay.

It is in the eastern division of the Piedmont that the granites are found. The drainage of this district flows to the east and southeast. Susquehanna and Potomac rivers, which drain directly into Chesapeake Bay, traverse it on its northern and southern boundaries. Among the larger intermediate streams which head on Parrs Ridge are Patuxent, Patapsco, and Gunpowder rivers. These streams are not navigable beyond the western limits of the fall line, and material quarried in that region must be shipped either by rail, canal, or wagon routes.

To the east of Parrs Ridge the rocks consist of highly metamorphosed sediments and a complex of intruded igneous masses which have been more or less metamorphosed, rendered schistose, or laminated. The highly metamorphosed sediments[b] comprise the following formations, which, according to the Maryland Geological Survey, range in age from Archean to Ordovician: The Baltimore gneiss, the Cockeysville marble, the Wissahickon mica gneiss, the Octoraro schist, the Cardiff quartzite, and the Peachbottom slate. The igneous rocks comprise extensive areas of gabbros, granites, and other plutonic types. The gabbros were intruded earlier than the granites, but the exact period of intrusion of the igneous masses is still somewhat uncertain. In addition to these, small dikes of acidic volcanic rocks (metarhyolite) occur along the lower Susquehanna in the vicinity of Frenchtown and Havre de Grace, and a series of Mesozoic diabase dikes can be traced with interruptions across the entire eastern part of the Piedmont district.[a]

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[a] Abbe, Cleveland, Jr., A general report on the physiography of Maryland, Maryland Weather Service, 1899, p. 117.

[b] Maryland Geol. Survey, vol. 6, 1906, pp. 105-113.

The western division of the Maryland Piedmont extends from Parrs Ridge to Catoctin Mountain. On its east side the rocks are scarcely distinguishable from those of the eastern division, but in the western part the rocks are much less metamorphosed. Semicrystalline sediments, chiefly limestone and sandstone of Cambro-Ordovician and Mesozoic age, and igneous rocks, chiefly Archean basic and acidic volcanic rocks and Mesozoic diabase, compose the rocks of this division.[b]

The rocks east of Parrs Ridge are more crystalline and the folding is a little more pronounced than in the western division of the Piedmont. The older rocks have suffered extreme metamorphism which has produced in them a marked lamination or schistosity, accompanied by recrystallization. Schistose structures, having a general northeast-southwest trend and variable dip, are developed in both the sedimentary and the igneous rocks.

DISTRIBUTION OF THE GRANITES.

The granites and gneisses of Maryland are limited to the Piedmont Plateau province (see Pl. I); and within this region the quarrying industry is confined to a triangular area between the Coastal Plain on the east and Parrs Ridge on the west, including the whole or parts of Cecil, Harford, Baltimore, Howard, and Montgomery counties. The granites occupy several distinct areas in the eastern division of the Piedmont Plateau. The largest of these areas extends from Sykesville southward to Washington and across the Potomac into Virginia. The most important, economically, is the lenticular area that extends southward from Rising Sun through Port Deposit and along the southwest side of Susquehanna River. Of the fifteen areas where granite is prominently developed, there are at least five which include quarries of considerable economic importance.[c] These are, named from north to south, (1) Port Deposit, (2) Frenchtown, (3) Ellicott City, (4) Woodstock, and (5) Guilford. Besides these there are several minor areas in which quarries have been worked from time to time to supply the local demand for stone. The most important of the smaller areas is that of Dorseys Run, on the Baltimore and Ohio Railroad between Ellicott City and Woodstock.

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[a] Maryland Geol. Survey, vol. 6, 1906, pp. 113–118.

[b] Idem, pp. 118–123.

[c] Mathews, E. B., An account of the character and distribution of Maryland building stones, together with a history of the quarrying industry: Maryland Geol. Survey, vol. 2, 1898, p. 138.

The others are Sykesville, Garrett Park and Brookville, Franklinville, Benson, Baldwin station in Cecil County, Texas, and Relay.

Quarries of gneisses of granitic composition have been operated for many years near and in the city of Baltimore, grouped about two centers—Jones Falls and Gwynns Falls, on the north and west sides of the city, respectively.

SCIENTIFIC DISCUSSION.

VARIETIES OF THE GRANITE.[a]

On the basis of mineral composition the Maryland granites are divisible into the following leading types: (1) Biotite granite or granitite, under which most of the granites of the State may be grouped, including Port Deposit, Frenchtown, Woodstock, Dorseys Run, Texas, Ellicott City, and Ilchester among the most important areas. In addition to biotite, the granites of some of the Port Deposit localities, of Woodstock, Dorseys Run, Ellicott City, and Ilchester contains considerable epidote and allanite, and may be designated as allanite-epidote granitite; (2) muscovite-biotite granite, of which the Guilford area is the only typical representative; and (3) hornblende-biotite granite, represented by the granites occurring northeast of Washington, near Garrett Park, and near Rowlandsville, in Cecil County.

Structurally there are three rather well-marked types of the Maryland granites—(1) even-granular (massive) granites; (2) porphyritic granites; and (3) banded or schistose granites (granite gneisses). To these should be added the two subvarieties graphic granite and pegmatite. Quarries are worked in some of the larger pegmatites for feldspar.

MINERAL COMPOSITION.

Conforming with other well-known granites, the Maryland rocks are made up of a mixture of quartz and feldspar with biotite usually as the third essential mineral. Orthoclase, abundant plagioclase (oligoclase), and microcline in variable amount compose the feldspathic constituent. Biotite is an important constituent in all the granites of the State. In some of the areas it is associated with hornblende; in others with muscovite, epidote, and allanite. In the granites near Garrett Park and Rowlandsville hornblende forms an important constituent and is about equal in amount to biotite. At Guilford muscovite occurs with biotite as an important mineral. Besides these there occur magnetite, apatite, zircon, titanite, and locally some other minerals.

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[a] Williams, G. H., Petrography and structure of the Piedmont in Maryland: Bull. Geol. Soc. America, vol. 2, 1891, p. 321; The general relations of the granitic rocks in the middle Atlantic Piedmont Plateau: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 657-684.

Keyes, C. R., The origin and relations of the central Maryland granites: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 714-718.

Examination of the table of analyses of the Maryland granites given below discloses the fact that in about half of them soda is equal to or greater than potash, indicating the prevailingly large quantity of plagioclase (soda-lime feldspar) present in these rocks. Again, one of the most striking features of the Maryland granites is the prevalence of microcline, which has developed in part from orthoclase by pressure metamorphism.

The granites of some of the Port Deposit localities, of Woodstock, Dorseys Run, Ellicott City, and Ilchester,[a] contain a considerable quantity of epidote and allanite as important characteristic constituents, and for this reason they were grouped by Keyes[b] as allanite-epidote granites.

CHEMICAL COMPOSITION.

Variation in the chemical composition of the granites and gneisses of Maryland and the District of Columbia is indicated in the analyses of these rocks, which follow:

Analyses of Maryland and District of Columbia granites and gneisses.

[Analysis 1, by William Bromwell; analyses 2-12, by W. F. Hillebrand; analysis 13, by G. P. Merrill.]

Constituents.	1.[a]	2.	3.	4.	5.	6.	7.	8.[b]	9.[c]	10.[c]	11.[c]	12.[c]	13.[d]
SiO_2	73.69	74.87	72.57	71.79	71.45	70.45	69.33	66.68	62.91	67.22	63.43	78.28	69.33
Al_2O_3	12.89	14.27	15.11	15.00	14.36	15.98	14.33	14.93	19.13	15.34	16.69	9.96	14.33
Fe_2O_3	1.02	Tr.	1.02	.77	2.07	.75	......	1.58	.98	2.78	3.36	1.85	......
FeO	2.58	.51	.59	1.12	2.78	1.84	3.60	3.23	3.20	3.41	3.87	1.78	3.60
MgO	.50	.16	.30	.51	1.17	.77	2.44	2.19	1.69	1.65	2.33	.95	2.44
CaO	3.74	.48	1.65	2.50	1.58	2.60	3.21	4.89	4.28	1.36	.80	1.68	3.21
Na_2O	2.81	3.06	3.92	3.09	1.95	3.83	2.70	2.65	3.94	2.00	2.38	2.73	2.70
K_2O	1.48	5.36	4.33	4.75	3.28	3.59	2.67	2.05	3.38	3.26	3.22	1.35	2.67
H_2O- at 110° C.	1.06	.66	.47	.64	1.30	.45	1.22	1.09	.63	.29	.23	.12	1.22
H_2O+ at 110° C.		.26						.16		1.68	2.67	.83	
TiO_2	......	.05	......	......	......	......	......	.50	......	.84	.91	.70	Not det.
P_2O_5	......	.21	......	......	......	......	.10	.10	......	.14	.11	.11	......
MnO	......	Tr.	......	......	......	......	......	.10	......	.13	.09	.08	......
BaO	......	......	......	......	......	......	......	.08	......	.04	.03	.02	......
SrO	......	......	......	......	......	......	......	Tr.	......	Tr.	Tr.	Tr.	Tr.
Li_2O	......	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
	99.77	99.89	99.90	100.17	99.94	100.26	99.26	100.23	100.14	100.14	100.12	100.44	99.60

[a] Mathews, E. B., Maryland Geol. Survey, vol. 2, 1898, p. 142. (See Grimsley, G. P., Jour. Cincinnati Soc. Nat. Hist., vol. 17, 1894.)

[b] Bascom, F., Geology of the crystalline rocks of Cecil County: Cecil County Rept., Maryland Geol. Survey, 1902, p. 120.

[c] Williams, G. H., The general relations of the granitic rocks in the middle Atlantic Piedmont Plateau: Fifteenth Ann. Rept. U. S. Geol. Survey (1895), pp. 670, 672.

[d] Merrill, G. P., A treatise on rocks, rock weathering, and soils, New York, 1906, p. 186.

1. Biotite granite (quartz monzonite), Port Deposit, Cecil County, Md.
2. White granite, Brookville, Montgomery County, Md.
3. Muscovite-biotite granite, Guilford, Howard County, Md.
4. Biotite granite, Woodstock, Baltimore County, Md.
5. Biotite granite, Sykesville, Carroll County, Md.
6. Biotite granite dike, Dorseys Run cut, Howard County, Md.
7. Biotite granite gneiss, Broad Branch quarry, District of Columbia.
8. Hornblende-biotite granite, Rowlandsville, Cecil County, Md.
9. Biotite granite, Dorseys Run cut, Howard County, Md.
10. Gneiss from Potomac Stone Company's quarry, 1 mile below the Chain Bridge, District of Columbia.
11. Chloritic gneiss from Emery's store, northwest of Cabin John Bridge, Montgomery County, Md.
12. Gneiss from second lock at Great Falls, Montgomery County, Md.
13. Foliated biotite granite from the District of Columbia.

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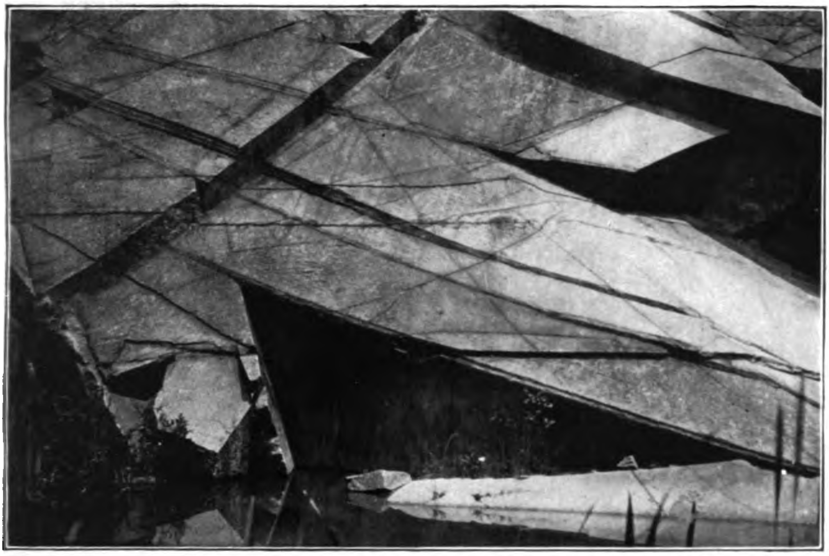
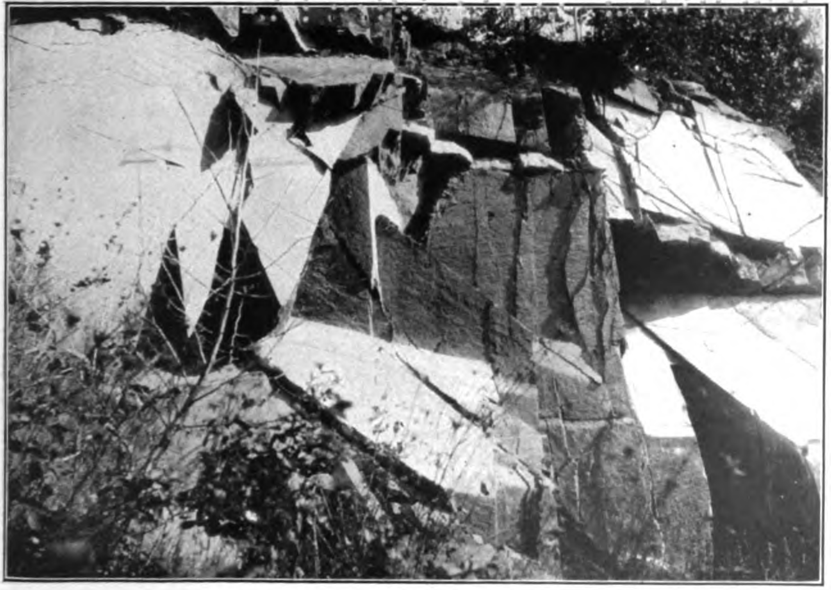
[a] Hobbs, W. H., Johns Hopkins Univ. Circ., vol. 7, No. 65, 1888, p. 70; Am. Jour. Sci., 3d ser., vol. 38, 1889, p. 223; Tschermaks Min. pet. Mitt., vol. 11, 1890, p. 1.

[b] Keyes, C. R., The origin and relations of central Maryland granites: Fifteenth Ann. Rept. U. S. Geol. Survey, 18 5, p. 717.



A.



B.

QUARRIES NEAR GLEN ECHO, MD.

A. Joints and faults. *B.* Intersecting joints.

The high soda content in the Maryland granites in general has been commented on above. In many of the analyses soda equals or exceeds potash, indicating in these the predominance of plagioclase (soda-lime feldspar) over orthoclase (potassic feldspar), which places the granites with the quartz-monzonite type.

Analysis 12 in the table does not correspond to any known igneous type, but is in close agreement with certain siliceous sediments; as Williams[a] remarks, "so far as the chemical evidence can be relied upon, we may safely regard the rock as of sedimentary origin." The other gneisses represented by analyses in the table are of igneous origin.

STRUCTURAL FEATURES.

JOINTS.

Jointing, both vertical and horizontal, is prominently developed in the Maryland granites (see Pl. II, *A*, *B*), and a third set of diagonal joints is distinct in many of the quarries. The courses of many of the principal vertical joints are N. 30°–35° E., N. 40°–45° E., and N. 55°–60° E.; N. 10° W., N. 40°–45° W., and N. 60°–70° W.; north-south, and east-west. The joints of the dominant system extend approximately northeast and northwest, east-northeast and west-northwest. The spacing of the joints varies considerably, ranging from less than 1 foot to more than 20 feet, but is usually from 6 to 15 feet.

The horizontal joints, prominent in all the larger quarries, separate the granite into sheetlike masses, which usually have their strongest development near the surface, but in some quarries extend to the entire depth of working. Nowhere is this better shown among the Maryland granites than in the old Guilford and Waltersville Granite Company's quarry in the Woodstock area (Pls. IV, *B;* VI, *B*). The sheets may vary from a few inches in thickness at or near the surface to 2 to 10 feet at some distance below the surface. In the quarries on the Baltimore County side of Patapsco River, at Ellicott City, sheeting extends to the depth of working, more than 90 feet, and the sheets range in thickness from 2 to 4 feet. In the quarries of the Woodstock area the sheets are from 2 to 6 feet thick, and in the quarries of the Guilford area from 3 to 10 feet thick. Approximately the same range in thickness is shown in the Port Deposit quarries, one of which has been worked to the extreme depth of 230 feet.

Some movement in the granite masses is indicated in the slickenside joint surfaces of the larger quarries. Slickensides are especially noticed on some of the joint surfaces in the quarries at Port Deposit, Frenchtown, Ellicott City, and Guilford.

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[a] Williams, G. H., op. cit., p. 670.

SCHISTOSITY.

The Maryland granites, and indeed the granites of the Southern States generally, strongly contrast in the amount of foliation secondarily induced in them by pressure metamorphism. The granites of Ellicott City, Woodstock, and Guilford show little or no pressure effects, but are massive. Those near Sykesville, Texas, and Rowlandsville, and the Murdoch Mill area west of Washington are slightly foliated, but not sufficiently so to disguise their essential features. In the Port Deposit region and in the Broad Branch area west of Washington secondary foliation has resulted in a complete rearrangement of the constituents,[a] and the rocks are more properly designated granite gneisses.

In the Piney Run type, which occupies a considerable area south of Laurel and on Potomac River, extreme foliation has obliterated most of the original granite features. Concerning this type Williams says:[b] "It is only because of the abundance of indistinct masses resembling inclusions which are scattered through it that we assume for this rock an igneous origin."

DIKES.

GRANITE.

In some of the granite areas true granite dikes penetrate the rocks into which the granite was intruded and are to be regarded as apophyses. These are described by Keyes[c] as being especially well developed and exposed in the railroad cut at Dorsey Run, where dikes of very light colored, fine-grained granite penetrate gneiss and, as shown in the analyses below, are more acidic than the main massive granite and also finer grained in texture. The more acidic, finer-grained granite dikes also penetrate the more massive granite as well as the gneiss.[d]

Analyses of granite from dikes at Dorsey Run, Md.

Constituents.	1.	2.
Silica (SiO_2)	62.91	70.45
Alumina (Al_2O_3)	19.13	15.98
Ferric oxide (Fe_2O_3)	.98	.75
Ferrous oxide (FeO)	3.20	1.84
Magnesia (MgO)	1.69	.77
Lime (CaO)	4.28	2.60
Soda (Na_2O)	3.94	3.83
Potash (K_2O)	3.38	3.59
Water (H_2O)	.63	.45
Lithia (Li_2O)	Trace.	Trace.
	100.14	100.26

1. Typical granite from selected average specimens of the large granite mass; W. F. Hillebrand, analyst; Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 722.
2. Selected specimens from the light-colored granite dikes; W. F. Hillebrand, analyst; idem, p. 722.

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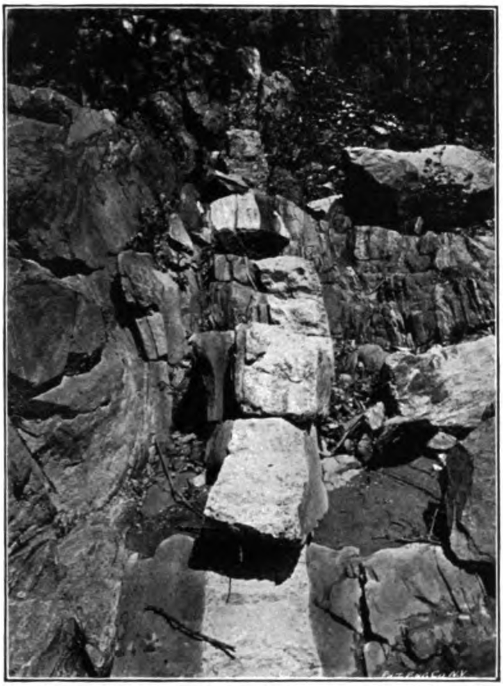
[a] Williams, G. H., op. cit., p. 669.

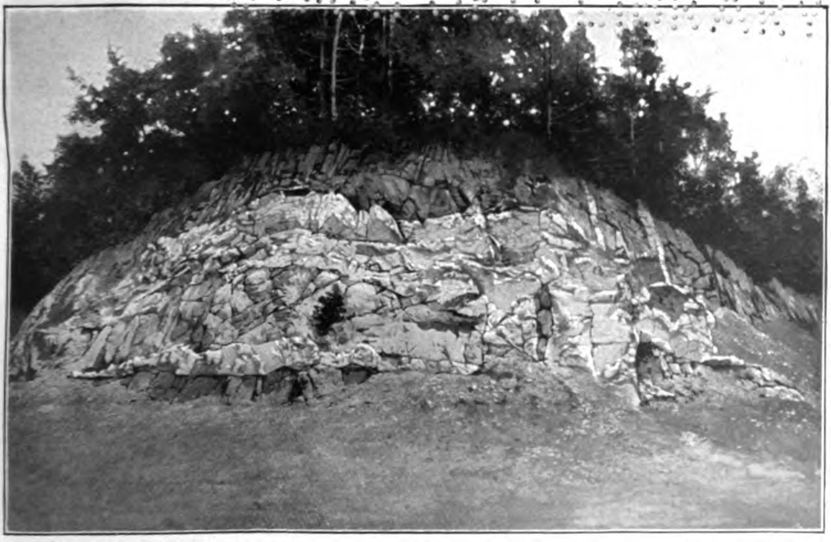
[b] Idem, p. 669.

[c] Keyes, C. R., Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 722-723.

[d] Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pl. xxxvii, fig. 3, p. 694.



A.



B.

PEGMATITE DIKES, MARYLAND.

A. Ilchester station. *B.* Orange Grove.

Granite dikes of dark-gray color and fine-grained texture, not exceeding 6 feet in width and striking N. 60° E., penetrate the porphyritic granite of Weber's quarry at Ellicott City. At Port Deposit, in the rear of Mr. McClenahan's residence, the granite is penetrated by a dike of foliated dark basic rock, 7 feet wide and nearly vertical. A second dike of similar character is exposed in the granite cliffs along the path leading from the town to Tome Institute.

PEGMATITE.[a]

Pegmatites and quartz veins are largely developed in the Maryland Piedmont region, where they traverse indiscriminately all the formations of both sedimentary and igneous rocks. The pegmatites differ from the quartz veins mineralogically in the addition of an alkali feldspar and muscovite or biotite. They are essentially very coarse crystallizations of quartz and feldspar aggregates, with more or less mica. In width they vary from a few inches up to several hundred feet (Pl. III, *A*, *B*), and can be traced for considerable distances on the surface. They may either break through or cut across the schistosity of the inclosing gneisses.

Some of the pegmatites have probably had an origin similar to that of the widely distributed quartz veins; others, usually of smaller dimensions and wholly inclosed by the granite mass, have probably been formed by a process of segregation; while still others seem to show equally strong evidence of an intrusive origin. As a rule the rock composing the dikes of an intrusive character is a muscovite granite, essentially similar to the granite which it intrudes, except that it is more acidic. The minerals composing dikes of this class are quartz, orthoclase, microcline, albite, muscovite, and a few small crystals of red garnet. Williams[b] has shown that these dikes of pegmatite agree closely in composition with the large masses of granite, and are quite independent of the character of the rocks which surround them. The Maryland pegmatites, according to Williams, belong to the youngest periods of the granitic intrusion and show little or no effect of dynamic metamorphism.

The Maryland pegmatites are not especially rich in unusual minerals. They have become of economic importance within recent years for their feldspar and quartz (flint) content, especially the feldspar, and have been worked in Baltimore, Howard, Harford, and Cecil counties. The principal producing area is in the vicinity of Woodstock, Howard County, and in the adjacent portion of Baltimore County. As is indicated in the analyses below, the feldspar of these dikes belongs partly to the potassic and partly to the sodic varieties.[c]

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[a] For a detailed description of the Maryland pegmatites and their origin, see Williams, G. H., General relations of the granitic rocks in the middle Atlantic Piedmont Plateau: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 657-684.

[b] Idem, p. 683.

[c] Mineral Resources U. S. for 1906, U. S. Geol. Survey, 1907, pp. 1257, 1260. Maryland Geol. Survey, Cecil County, 1902, pp. 96, 97, 101-103, 217, 218.

Analyses of feldspar from Maryland pegmatites.

Constituents.	1.	2.	3.
Silica (SiO_2)	65.96	68.60	64.62
Alumina (Al_2O_3)	19.53	19.10	20.57
Ferric oxide (Fe_2O_3)	.24	.14	Trace.
Magnesia (MgO)	None.	.28	2.36
Lime (CaO)	.18	Trace.	.14
Soda (Na_2O)	1.13	2.09	10.27
Potash (K_2O)	12.92	9.03	1.94
	99.96	99.24	99.90

1. Potash feldspar from quarry of Guilford and Waltersville Granite Company, Woodstock, Howard County, Md. Partial analyses of other specimens from the same quarry made at the Maryland agricultural experiment station show 13.2 per cent potash with 1.8 per cent soda, and 13.5 per cent potash with 1.6 per cent soda. (Quoted by E. S. Bastin, Mineral Resources U. S. for 1906, U. S. Geol. Survey, 1907, p. 1259.)
2. Potash-soda feldspar; quarry of Walter F. Patterson, jr., Henryton, Carroll County, Md. Analysis by Pittsburg Testing Laboratory (Limited). (Quoted by E. S. Bastin, op. cit., p. 1257.)
3. Soda feldspar, variety albite, from quarry of Sparavetta Mining Company, Chester County, Pa., near Sylmar, Md. (Quoted by E. S. Bastin, op. cit., p. 1257.)

QUARTZ VEINS.

Like the pegmatite dikes, quartz veins are numerous over parts of the eastern division of the Maryland Piedmont, and the two are as a rule closely associated. Many of the veins assume large dimensions, and they traverse the formations indiscriminately. Though in many places concealed by soil covering, their abundance is indicated locally by the innumerable quartz fragments strewn over the surface.

Quartz veins have been observed actually penetrating the granite in quarries of two Maryland localities, Frenchtown and Port Deposit, Cecil County. They are, however, by no means numerous, and they do not exceed 12 inches in width, the average probably being only 1 or 2 inches. They are apparently more abundant, in the same granite, in the high and steep cliffs along the north side of Susquehanna River at and just below the town of Port Deposit. The course of the quartz veins in the Frenchtown quarries is N. 60° E.

INCLUSIONS.

Inclusions of foreign rocks, including sedimentary and eruptive kinds, incorporated in the granites at Sykesville, Woodstock, Dorseys Run, and Garrett Park, were described in some detail by Keyes.[a] They comprise irregular fragments and blocks of all sizes and shapes identical with the neighboring rocks. For the most part they display characteristic border zones of complete alteration with essentially unaltered interiors.

The inclusions were found in greatest abundance in the granite at Sykesville. Among the various foreign rock fragments noted by Keyes in this granite were limestone, soapstone, pyroxenite, vein quartz, and hornblende and biotite gneisses. The granite at Woodstock shows similar phenomena equally well. The incorporated fragments are mostly gneiss; many of them are puckered and wrinkled and some measure 10 feet. Inclusions of gneiss usually exhibit only a very narrow marginal metamorphosed zone. In the small openings made in the Garrett Park outcrops, a few miles northeast of Washington, numerous irregular blocks of dark gneiss are in places incorporated in the granite. Similar fragments and blocks derived from a near-by gneiss are shown in the granite at Dorseys Run.

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[a] Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 722, 723, 724, 726–729, 732.

A chemical analysis, made by W. F. Hillebrand, of the United States Geological Survey, of a large assortment of inclusions in the granite on Dorseys Run, is given by Keyes:[a]

Analysis of inclusions in granite from Dorseys Run.

Silica (Si_2O)	57.33
Alumina (Al_2O_3)	15.31
Ferric oxide (Fe_2O_3)	3.39
Ferrous oxide (FeO)	8.19
Magnesia (MgO)	4.36
Lime (CaO)	3.95
Soda (Na_2O)	1.22
Potash (K_2O)	4.57
Water (H_2O)	1.80
Lithia (Li_2O)	Trace.
	100.12

In his description of the granitoid rocks which emerge from beneath the Coastal Plain south of Laurel and extend across the Potomac into Virginia, Williams says:[b]

> These rocks, though typical gneisses in their structure, are filled with what seem to be inclusions of foreign rock, especially of vein quartz and irregular fragments of similar though older gneisses. They may best be studied along the Potomac, between Washington and the Chain Bridge, where they are extensively exposed in the great quarries. They are also typically shown near the north end of Analostan Island, at the Falls of the Patuxent west of Laurel, and along Sligo Branch, Piney Run, and the lower portions of Rock Creek, near Washington. They may also be seen to advantage where Fourmile and Holmes runs have cut deeply into the Coastal Plain deposits in Fairfax County, south of Washington.

BASIC SEGREGATIONS (KNOTS).

Segregations of the ferromagnesian minerals do not seem to be so abundant in the Maryland granites as in some of the granites in others of the Southern States. A small quarry opening made near Garrett Park on the south side of Rock Creek, near the Rockville road, is in a light-colored granite poor in ferromagnesian minerals. Keyes[c] reports numerous basic secretions of lenticular shape and various sizes in the granite. Occasional dark segregations (knots), few of them exceeding 12 inches in size, were observed by the writer in the granite quarries opened at Port Deposit, Frenchtown, Ellicott City, Woodstock, and Guilford. They were most abundant in the quarries opened along Patapsco River on the Baltimore County side, opposite Ellicott City. In these quarries many of the knots are drawn out parallel to the schistosity of the granite and measure as much as 2 feet in length.

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[a] Keyes, C. R., op. cit., pp. 722, 723.

[b] Williams, G. H., op. cit., p. 665.

[c] Op. cit., p. 730.

The percentage of silica in and the specific gravity of the basic segregations (knots) in the granite at Port Deposit are compared with those of other well-known granites on page 30.

PHYSICAL TESTS.

ABSORPTION TESTS.

Figures obtained by Merrill[a] showing the relative amount of water absorbed by some of the well-known granites and gneisses of Maryland are given in the following table:

Absorption tests of Maryland granites and gneisses.

Kind of stone.	Weight after drying 24 hours at 212° F.	Weight after immersion 24 hours in water.	Gain in weight.	Absorption.
	Grams.	*Grams.*	*Grams.*	*Per cent.*
Granite, Port Deposit	351.33	352.22	0.89	0.253
Do	341.34	342.00	.66	.196
Granite, Woodstock	340.43	341.31	.88	.258
Do	340.45	341.24	.79	.232
Gneiss, Baltimore	354.37	355.07	.70	.197
Do	323.36	326.97	3.61	1.116

A second set of experiments was conducted by E. B. Mathews[b] on blocks of the same size (2-inch cubes) as those of the first set.

Absorption tests of Maryland granite and gneiss.

Kind of stone.	Weight, air dry.	Weight after immersion one hour.	Weight after immersion one day.	Weight after immersion one week.	Gain in weight.	Absorption.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Granite, Woodstock	345.00	345.50	345.50	345.55	0.05	None.
Gneiss, Baltimore	350.70	350.65	350.70	350.67	....	None.

The tests show that practically no water is absorbed by the specimens. Merrill states that the weather during the experimenting was warm (85° to 95° F.), and the humidity was approximately 70 per cent.

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[a] Merrill, G. P., The physical, chemical, and economic properties of building stones: Maryland Geol. Survey, vol. 2, pt. 2a, 1898, p. 94.

[b] Quoted by Merrill, G. P., loc. cit., p. 94.

MISCELLANEOUS TESTS.

Tests to ascertain resistance to freezing were made on 1-inch cubes of granite from Port Deposit, Cecil County, and from Great Falls, on Potomac River, Montgomery County, Md., with the following results.[a]

Freezing tests of Maryland granites.

Locality.	Specific gravity.	Loss, in grains.
Port Deposit	2.609	5.05
Great Falls	....	.35

Merrill states that the inch cubes were immersed for half an hour in a boiling solution of sulphate of soda and then hung up to dry, this performance being repeated daily throughout the four weeks of the experiment. The result is assumed to be analogous to that of freezing.

Strength and other physical tests of granite from Port Deposit were made by Gillmore[b] with the following results:

Miscellaneous tests of granites from Port Deposit, Md.

Position.	Cracked.	Strength of specimen.	Strength per square inch.	Specific gravity.	Weight of 1 cubic foot.	Ratio of absorption.	Remarks.
	Pounds.	*Pounds.*	*Pounds.*		*Pounds.*		
On bed	....	79,000	19,750	2.720	170	0	Coarse, strongly dashed with black.
On edge	33,000	52,400	13,100	2.720	170	0	Do.
On bed	....	66,000	16,000	2.720	170	0	Do.
Do	....	60,000	15,000	2.720	170	0	Burst suddenly.

Concerning the following tests, Mathews[c] states that the specimens were 2-inch cubes carefully prepared and subjected to tests under the most uniform conditions:

Strength, absorption, and freezing tests of Maryland granites.

Simple crushing.		Absorption gain.	Freezing loss.	Crushing after freezing.	
Crack.	Break.			Crack.	Break.
Pounds.	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*
....	67,100	0.253	0.006	83,000	86,000
....	79,200	.193	.011	78,100	90,800
....	86,200	....	....	....	....
....	101,540	....	....	....	....

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[a] Merrill, G. P., op. cit., p. 105.

[b] Gillmore, Reports on the compressive strength, specific gravity, and ratio of absorption of the building stones in the United States: Rept. Chief of Engineers for 1875, appendix 2, p. 847; republished 8, 37 pp., Van Nostrand, New York, 1876. (Quoted by Mathews, E. B., Maryland Geol. Survey, vol. 2, 1898, p. 144.)

[c] Mathews, E. B., Maryland Geol. Survey, vol. 2, 1898, p. 145.

Tests made by Messrs. Booth, Garrett, and Blair, of Philadelphia, on a 2-inch cube of the granite from Port Deposit gave the crushing strength as 84,730 pounds, which is equivalent to 21,180 pounds per square inch.[a]

Mathews[b] reports the following tests on specimens from the Waltersville quarries at Woodstock:

Strength, absorption, and freezing tests on granite from Woodstock.

Simple crushing.		Absorption gain.	Freezing loss.	Crushing after freezing.	
Crack.	Break.			Crack.	Break.
Pounds.	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*
79,700	85,700	0.258	0.011	79,400	102,200
79,200	83,420	.232	.029	86,800	90,300

Mathews[c] gives the following results of tests made on the gneiss from the extensive quarries on Jones Falls, at the northern limits of the city of Baltimore:

Strength, absorption, and freezing tests on gneiss from Jones Falls.

Kind of stone.	Crushing.		Absorption gain.	Freezing loss.	Crushing after freezing.	
	Crack.	Break.			Crack.	Break.
	Pounds.	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*
Quartzose layers ("blue stone")	66,700 85,940	70,140 96,300	0.197	0.028	80,118	118,000
Feldspathic layer ("biotite granite")	 78,600	94,200 103,500	1.116	.052	63,060	84,220

INDIVIDUAL QUARRY AREAS.

GENERAL STATEMENT.

The granitic rocks of Maryland are discussed below by areas under (*a*) granites and (*b*) gneisses.

Under granites are included the even-granular granites and their porphyritic facies and the massive and foliated varieties of both. Porphyritic granites are of very minor extent and are merely local facies of the larger even-granular masses. They are represented in the Ellicott City, Relay, and Texas areas. Of the massive, even-granular granites, the Guilford and Woodstock areas are the most typical. In most of the other areas a foliated or gneissic structure, resulting from pressure metamorphism, is more or less developed in the granite masses. Granite gneisses, or foliated granites, the most typical representatives of which are those of Port Deposit and Frenchtown, are also included under granites.

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[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 964.

[b] Mathews, E. B., op. cit., p. 156.

[c] Idem, p. 164.

Under gneisses are included the highly crystalline, banded rocks of granitic composition of alternating hornblendic and micaceous types, belonging chiefly to the Baltimore gneiss. They are typically represented at the western and northern limits of the city of Baltimore about two principal centers, Gwynns Falls and Jones Falls.

GRANITES.

ELLICOTT CITY AREA.

GENERAL STATEMENT.

As indicated on the map (Pl. I), the Ellicott City granite area comprises an irregular L-shaped mass, which has an extreme length of about 5 miles in an east-west direction and a width varying from one-half mile to 2 miles. On the north, west, and south the granite mass is bordered by a large gabbro area, and on the east by gneiss. Much of the area is overlain by the Coastal Plain gravels and clays of Lafayette and Potomac ages. All the streams in the area have cut through this thin covering of recent sediments into the underlying older crystalline rocks, allowing the ready determination of the boundaries of the granite, gabbro, and gneiss. The best exposures of the granite occur along the gorge of Patapsco River at Ellicott City, where quarries have been opened.

The quarries are located on both sides of Patapsco River in Baltimore and Howard counties, about 9 miles west of Baltimore, and the granite in which they occur extends as far east as Ilchester on the east side of the river, but only as far as Grays siding on the west side. On the east or Baltimore County side of the river the granite has a decided foliated or gneissic structure, but on the west or Ellicott City side, in Howard County, the granite is massive and of porphyritic texture. The date of opening of the quarries is unknown, but was probably some time in the latter part of the eighteenth century. The foliated granite from the quarries opened opposite Ellicott City, on the Baltimore County side, was used in building the Cathedral in Baltimore, in 1806 to 1812 and 1815 to 1821. This was doubtless one of the most important stone structures in the United States at the time of its construction.

DESCRIPTIONS OF QUARRIES.

BALTIMORE COUNTY.

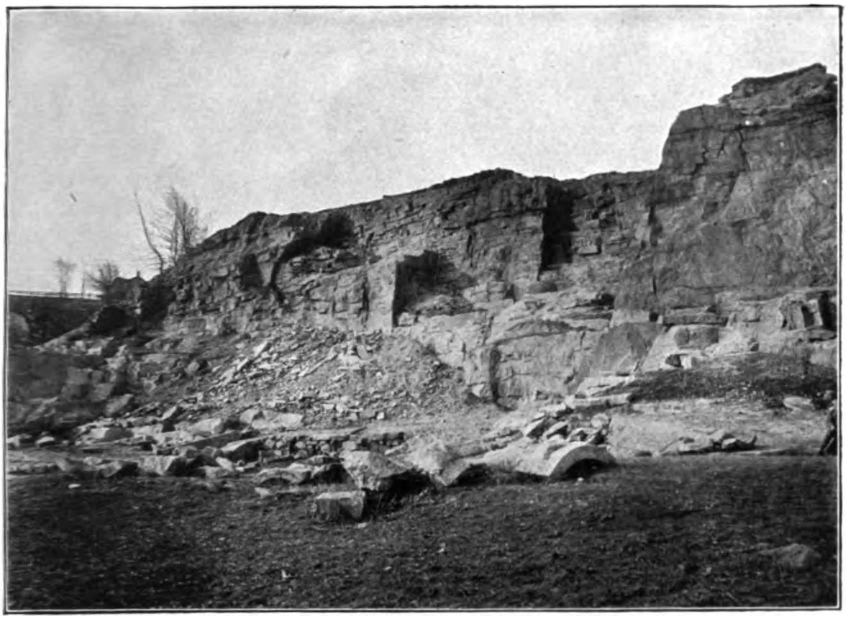
Several quarries opened in the steep and moderately high granite cliffs along the east side of Patapsco River have been operated nearly opposite Ellicott City. The largest of these, known as the *Gaither quarry*, comprises two large openings that adjoin each other and have been worked back from the river into the granite cliffs, with an elevation from the base to the top of about 75 feet. (See Pl. IV, *A*.)

The rock is a biotite granite of medium dark blue-gray color and medium grain. Its structure is decidedly foliated or schistose, though much less pronouncedly so than that of the granite gneiss at Port Deposit and Frenchtown; and its original granite characters are still apparent. Hand specimens of the granite show abundant fine granules of yellow epidote closely associated with the biotite. Irregular grains of brownish allanite are also apparent in the hand specimens. Because of its richness in epidote and allanite Keyes classified this granite and some of the granites from the Port Deposit, Woodstock, Dorseys Run, and Ilchester localities as allanite-epidote-bearing granites.

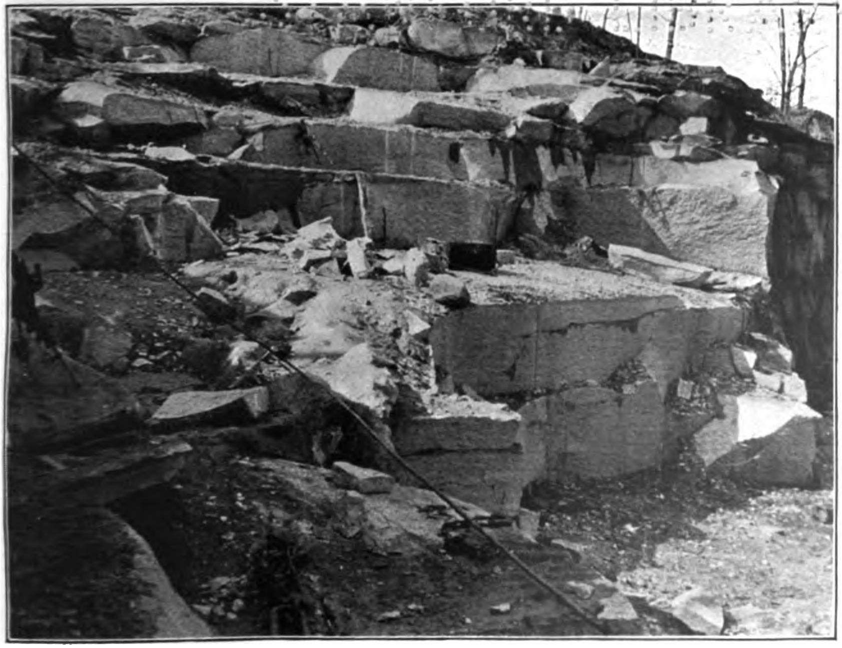
The granite consists of soda-lime feldspar (oligoclase), potash feldspars (orthoclase and microcline), quartz, and biotite, together with accessory zircon, apatite, hornblende, allanite, epidote, and secondary chlorite and epidote. Intergrowths of the feldspar and quartz in more or less rounded grains are of common occurrence. The feldspar is partly cloudy and opaque from alteration, and the larger individuals inclose small rounded grains of feldspar and quartz. Allanite and epidote occur as parallel growths. Partial granulation of the quartz and feldspar into fine mosaics from pressure metamorphism is pronounced.

The structure of the granite both in the quarry and in the hand specimens is schistose or foliated. Vertical joints strike N. 40° E. and N. 60° to 70° W. Many joints of the N. 40° E. course observe southeast (70°) and northwest dips. Some joints of the N. 60° to 70° W. course show curved faces. Horizontal joints, separating the granite into sheetlike masses of varying thickness, are well developed to the entire depth of the quarry opening—about 75 feet. The vertical joints are spaced at intervals of 2 inches to 6 feet, and the horizontal joints give sheets from 2 to 4 feet thick at the bottom of the quarry. Slickensides developed on the surfaces of some of the vertical joints indicate movement in the granite mass.

There are at this locality numerous pegmatite dikes ranging from a fraction of an inch to more than 12 inches thick, with an average thickness of less than 6 inches. These cut the granite indiscriminately, but most of them apparently conform to a N. 30° W. course. They contain biotite as the principal mica, with a flesh-colored feldspar and quartz as the chief constituents. Dark-colored segregations (knots), chiefly of biotite with some feldspar and quartz, much elongated or elliptical in shape, are abundant. These range up to more than 2 feet in length and usually show pronounced foliation parallel to that of the inclosing granite.



A. GAITHER'S GRANITE QUARRY, ELLICOTT CITY, MD.



B. GUILFORD AND WALTERSVILLE GRANITE COMPANY'S QUARRY NEAR WOODSTOCK, MD.

The granite is decayed from the surface downward to a depth that is more than 20 feet in some places, but is usually much less.

The quarries on the Baltimore side of Patapsco River, in the Ellicott City area, were idle when examined in 1908 and had not been worked for some time.

HOWARD COUNTY.

The *Weber quarry*, opened in moderately high cliffs along the Baltimore and Ohio Railroad on the opposite side of Patapsco River from the Gaither quarry, is the principal quarry in the Ellicott City area in Howard County. The opportunity for shipment is excellent, as the quarry is so close to the Baltimore and Ohio Railroad that cars are readily loaded by turning the derrick boom.

The granite is a porphyritic biotite granite of dark-gray color and medium grain and is massive. Its mineral composition is essentially the same as that of the granite of the Gaither quarry already described. The minerals are soda-lime feldspar (oligoclase), potash feldspar (microcline and orthoclase), quartz, very little muscovite, and accessory zircon, apatite, and allanite. Secondary minerals are chlorite and epidote. Intergrowths of feldspar and quartz are numerous. Many of the larger feldspar individuals inclose small, rounded grains of feldspar and quartz.

The feldspar phenocrysts are distributed without orientation through the granite groundmass. They show both crystal (idiomorphic) and noncrystal (allotriomorphic) boundaries, are in places twinned on the Carlsbad law, are of a pronounced red color, and contain abundant inclosures of biotite. The idiomorphic phenocrysts are usually flat-tabular in outline and are as much as 1½ to 2 inches long.[a]

Jointing is prominent and irregular and necessitates the working of the irregular masses into the desired shape by hand after quarrying. There are at least four sets of vertical joints; the principal set strikes N. 60° E. Slickensides characterize many of the joint surfaces. Horizontal joints are emphasized in the granite mass in the upper portion of the quarry. Dark basic segregations (knots) occur, but are not abundant.

A dike of even-granular biotite granite, 6 feet thick, of dark blue-gray color and fine grain, penetrates the porphyritic granite in a N. 60° E. course. A thin section of the dike granite showed soda-lime feldspar (oligoclase), potash feldspar (orthoclase and microcline), quartz, and biotite, together with accessory apatite and zircon and secondary chlorite and epidote. Intergrowths of feldspar and quartz are abundant.

The Weber quarry was the only quarry operating in the Ellicott City area at the time of examination in 1908.

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[a] See Maryland Geol. Survey, vol. 2, 1898, Pl. XI, for reproduction of a polished surface of a block of porphyritic granite from the Weber quarry.

GUILFORD AREA.

GENERAL STATEMENT.

The Guilford granite area, located in Howard County, a few miles southwest of the Ellicott City area, is of large size and irregular outline, as shown on the map (Pl. I). It is bordered on the north and west by the Baltimore gneiss and on the east by the gabbro. It is also covered in part by the gravels and clays of the Coastal Plain.

The granite from this area differs from that of the other areas in the State in containing both light mica (muscovite) and dark mica (biotite). Muscovite occurs as a subordinate constituent in some of the other Maryland granites, but not so abundantly nor characteristically as in the granite of this area.

The granite of the Guilford area varies from a coarse-grained granite of red color at the Guilford Granite and Stone Company's quarry through a medium-grained reddish-gray granite at the Penny quarry to a fine-grained medium-gray granite at the Maryland Granite Company's quarry. This last-named type is the one most extensively quarried, because it possesses durable qualities that give it a wide range of uses.

The quarries are located on Little Patuxent River about 5 miles northwest of Annapolis Junction and about 2 miles from the nearest railroad point—Savage Factory. They were opened about 1834 and were worked almost continuously until the outbreak of the civil war in 1860. Very little work was done from 1860 to 1893, but in 1893 the quarrying industry was revived and has continued to the present time.

DESCRIPTIONS OF QUARRIES.

Four quarries, located close together on Little Patuxent River, have been opened. These are, in order of importance, the Maryland Granite Company's quarry, Guilford and Waltersville Company's quarry, Penny quarry, and Guilford Granite and Stone Company's quarry.

The *Maryland Granite Company's quarry* is on the east side of Little Patuxent River 2 miles north of Savage Factory and about 5 miles northwest of Annapolis Junction. It is the principal quarry in the Guilford area and was the only one operating at the time of examination in 1908.

The rock is a muscovite-biotite granite of medium-gray color and of even, fine grain, with biotite uniformly disseminated and in excess of muscovite. It consists of potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and muscovite, together with accessory zircon and apatite and secondary chlorite, epidote, muscovite, and kaolinite. Intergrowths of feldspar and quartz are numerous. The larger feldspar grains show inclosures of feldspar and quartz. The stone takes a fine polish, the durability of which is favored by the smallness of the biotite scales.[a] A chemical analysis of this granite is given in column 3 of the table on page 42. The percentages of soda and potash show that the rock contains nearly equal amounts of the potash and soda-lime feldspars.

The quarry measures about 500 by 300 feet and has a depth of about 100 feet. The average depth of stripping is about 10 feet. The sheets, 3 to 10 feet thick, are approximately horizontal and tapering lenticular. Vertical joints strike north-south and east-west, recurring at wide intervals. Many of the joint surfaces are slickensided, indicating movement in the granite mass. There are a few dark basic segregations (knots), the largest observed not exceeding 6 inches long by 3 inches wide. No pegmatite dikes were noted.

The product is used chiefly for monuments, though much of it is used for general building purposes in the dressed and rough states, largely in the rough. Much of the coarse waste is worked into paving blocks. Very little of the stone is used for curbing and no crushed stone is produced.

The principal markets are in Maryland and Pennsylvania. Shipments have been made as far west as St. Louis and Chicago, north to New York, and South to Atlanta.

The *Guilford and Waltersville Granite Company's quarry* is on the east side of Little Patuxent River a short distance from the Maryland Granite Company's quarry. Work had been suspended sometime prior to the writer's examination in 1908.

The rock is a muscovite-biotite granite of medium-gray color and of even, fine grain, with biotite uniformly disseminated and in excess of muscovite. This granite appears to be identical in composition, color, and texture with that of the Maryland Granite Company's quarry, and is equally well adapted to the same uses.

The *Penny quarry* is on the north side of Little Patuxent River about 300 feet northeast of the Maryland Granite Company's quarry. The quarry was nearly filled with water at the time of the writer's examination in 1908, but during its activity it was operated by the Maryland Granite Company.

The quarry is a small one, less than 100 feet square and less than 50 feet deep. The granite is a biotite-muscovite granite of medium pinkish-gray color and medium-coarse grain. Its feldspar contrasts strongly in color with that of the Maryland Granite Company's granite in having a pronounced pinkish cast. The rock is also of coarser texture and differs in composition, muscovite being in excess of biotite. It consists of potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, muscovite, and biotite, together with accessory apatite, and zircon and secondary chlorite. Microcline and orthoclase are present in nearly equal proportion; the latter is intergrown with a second feldspar as microperthite. The feldspar shows very general alteration. The larger feldspar individuals inclose rounded grains of other feldspar and quartz. Intergrowths of feldspar and quartz are observed.

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[a] See Maryland Geol. Survey, vol. 2, 1898, Pl. XVI, for reproduction of a polished surface of a block of this granite.

Vertical joints strike north-south and east-west. Many of their surfaces show slickensides. Segregations (knots) and pegmatite dikes were not observed in the granite.

The *Guilford Granite and Stone Company's quarry* is on the opposite (west) side of Little Patuxent River from the Maryland Granite Company's quarry. It comprises three small openings, the largest one of which is about 75 by 60 feet and 50 feet deep. The object of the company was to produce crushed stone, and a large crusher was erected and operated near the quarry. Operations were suspended about four months prior to the writer's examination in March, 1908.

The rock is a biotite-bearing muscovite granite of pronounced reddish color and coarse grain. The feldspar which imparts the red color to the granite contrasts strongly with the dark glassy quartz. The granite of this quarry is similar in composition to that of the three other quarries in the Guilford area described above, except that muscovite is the principal mica and is greatly in excess of the biotite. The rock consists of potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, muscovite, and very little biotite, together with accessory apatite and zircon. Potash feldspar is in excess of soda-lime feldspar, and both are considerably altered. Orthoclase is intergrown with a second feldspar as microperthite. Intergrowths of feldspar and quartz occur.

The granite differs from the other granites quarried in the Guilford area in being coarser grained and of a more pronounced red color and in having a larger preponderance of muscovite over biotite.

Closely spaced vertical joints are prominently developed. There are several sets, intersecting at approximately right angles and recurring at such short intervals as to render the quarrying of dimension stone very doubtful.

WOODSTOCK AREA.

GENERAL STATEMENT:

The Woodstock granite area is located in the extreme southwest corner of Baltimore County, about 2 miles north of Woodstock, on the Baltimore and Ohio Railroad, in the Patapsco River valley. The area lies about 25 miles a little north of west of Baltimore. As indicated on the map (Pl. I), the granite forms an isolated oval-shaped area scarcely 2 miles in extent from northeast to southwest and 1 mile from northwest to southeast. Although small, this area is economically one of the most important in Maryland.

The granite is entirely surrounded by the Baltimore gneiss, of pre-Cambrian age, into which it is intruded. No dikes or apophyses of the granite have been observed penetrating the surrounding gneiss, but that the gneiss is older than the granite is shown by the large number of inclusions of the gneiss incorporated in the granite. These are described in some detail on pages 46–47.

The systems of horizontal and vertical joints are prominently developed in these quarries, especially in the Guilford and Waltersville (Pls. IV, *B*, and VI, *B*) and the Weller quarries.

A chemical analysis of the granite from Woodstock is given in column 4 of the table on page 42. A noteworthy item in this analysis is the large percentage of soda, which indicates the presence of much soda-lime feldspar.

The granite bowlders first attracted attention to this area and operations were begun about 1832–33. The principal demand at first was that by the Baltimore and Ohio Railroad for stone for bridge and culvert work. One of the most important of the early contracts for the granite from Woodstock was that for the Baltimore custom-house about 1873–74.

DESCRIPTIONS OF QUARRIES:

Several extensive quarries have been operated in the Woodstock area. These are the Guilford and Waltersville Granite Company's quarry, the Fox Rock quarry, the Weller quarry, and the Atherton quarry. The first two are the most important and extensive and, together with the Atherton, which had only recently been opened, were operating at the time of the writer's examination in March, 1908. The village of Granite is located within the quarry area. A railroad spur 2 miles long connects the quarry of the Guilford and Waltersville Granite Company with the main line of the Baltimore and Ohio Railroad at Putney & Riddle's bridge, about 1 mile east of Woodstock.

The *Guilford and Waltersville Granite Company's quarry* is the largest quarry in the area. The opening is roughly circular in outline, measuring about 500 by 600 feet, and is worked to an average depth of about 12 feet. (See Pl. IV, *B*.)

The rock is a biotite granite of medium-gray color and medium grain. Because of slightly increased biotite the granite is a fraction darker in color than the gray granite at Guilford and is of slightly coarser texture.[a] The granite consists of potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory zircon, apatite, and allanite and secondary chlorite, epidote, and muscovite. Orthoclase is partly intergrown with a second feldspar as microperthite. A part of the feldspar shows considerable alteration in some of the thin sections. Intergrowths of feldspar and quartz are abundant. The quartz shows strain shadows and is in places fractured from pressure metamorphism.

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[a] See Maryland Geol. Survey, vol. 2, 1898, pl. XIII, for a reproduction of a polished surface of a block of the granite from this quarry.

The sheets measure from 1½ to 6 feet in thickness and are approximately horizontal (Pl. VI, *B*). There are two principal sets of vertical joints, striking about northeast-southwest and northwest-southeast, and several minor sets having different courses. Many of the joint faces are curved irregularly. They are spaced at sufficiently wide intervals to permit the quarrying of blocks of almost any size. The rock contains some thin pegmatite dikes. A very few dark segregations (knots), of biotite chiefly, the largest rarely exceeding 12 inches in length, were observed.

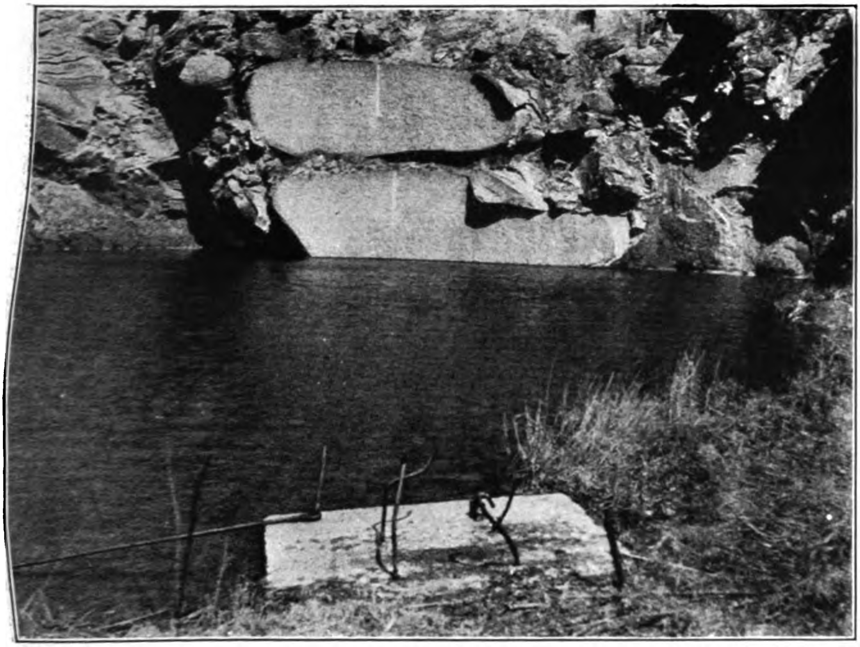
Physical tests made on specimens of this granite to determine absorption, compressive strength, and freezing loss, the results of which are given on pages 48, 50, show it to be a most durable stone. A chemical analysis is given on page 42 (No. 4).

The product is used chiefly for general building purposes, in both the rough and the dressed states. Other uses are for monuments, paving blocks, some curbing, and crushed stone (mostly for concreting). It is shipped to Maryland, Pennsylvania, New York, Delaware, Washington, D. C., and occasionally to Virginia and Ohio.

The *Fox Rock quarry* is the oldest one in the area and has been worked to an extreme depth of 96 feet. The rock is a biotite granite of medium-gray color and medium grain. It is entirely similar in color, texture, and composition to that of the Guilford and Waltersville quarry described above. It consists of potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and scant muscovite, together with accessory zircon, apatite, and allanite and secondary chlorite, muscovite, and epidote. The feldspars are partly intergrown in microperthitic structure, and some of them are cloudy and opaque from alteration. Intergrowths of feldspar and quartz are shown.

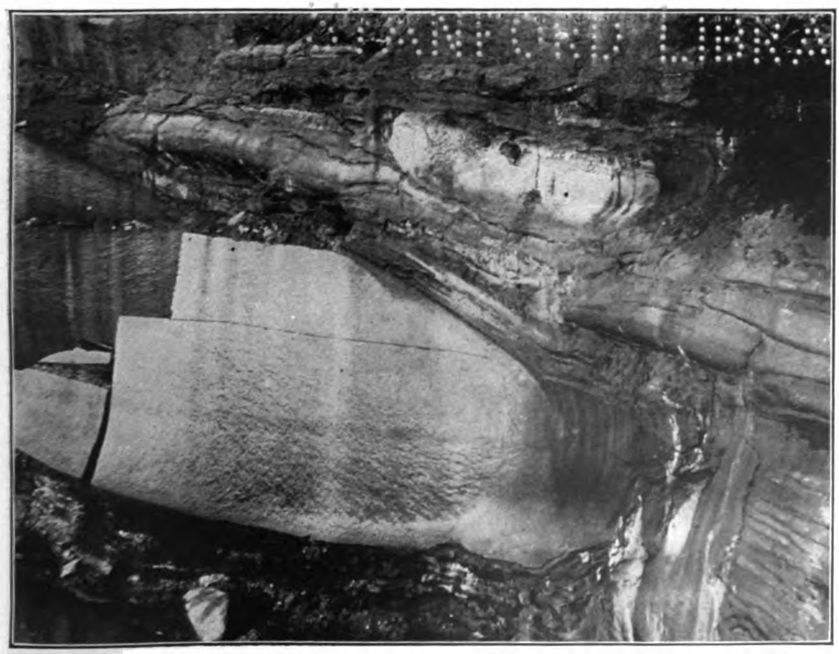
Vertical joints strike N. 55° E., N. 10° W., and N. 50° W., spaced at intervals of 8 inches to 4 feet and more. There are a few pegmatite dikes of small thickness. Occasional dark segregations (knots), of biotite chiefly, occur in the granite. The thickness of the decay at the surface ranges up to more than 15 feet in places.

The principal uses made of the product are for general building and monumental work and for street curbing and paving blocks. No crushed stone is produced. The product is shipped to Pennsylvania and West Virginia and to various points in Maryland. Occasionally it has been shipped as far west as Indiana and as far north as New York.



A. WELLER QUARRY, NEAR WOODSTOCK, MD.

Showing elongated concentric shells of granite.



B. LONG GRANITE COMPANY'S QUARRY, NEAR OGLESBY, GA.

Showing concentric weathering.

WEATHERING OF GRANITE.

The *Weller quarry* is adjacent to the Guilford and Waltersville quarry on the west. It was the only quarry in the area not operating at the time of examination, in March, 1908. It had apparently been idle for some time, as the opening, which is a large one, probably 300 feet long by 100 feet wide and 70 feet deep, was nearly filled with water, and very little could be seen of the actual quarry conditions. (See Pl. V.)

The rock is a biotite granite of the same color, texture, and composition as that at the Guilford and Waltersville and the Fox Rock quarries, already described. The effects of weathering along vertical and horizontal systems of joints are probably the most characteristic to be found within the State. Keyes[a] has described it as follows:

> The quarry ledge has the appearance of a great wall of cyclopean masonry, layer upon layer of huge blocks, rising one upon another with the regularity and precision of human workmanship. The separate blocks are more or less oblong in shape, and often measure 15 to 20 feet in length and from 2 to 8 feet in height. They are all more or less rounded, the spaces between the different bowlders being filled with incoherent granitic sand, derived from the decomposed edges and the sides of the blocks. It is quite evident that the granitic mass was originally everywhere jointed, and that atmospheric decay took place much faster on the edges and corners than on the flat sides of the great fragments, thus quickly rounding and forming them into bowlders like those found throughout drift areas. The sandy matrix is usually from 5 to 10 inches in thickness. The interior of the bowlders is perfectly fresh, and affords the best of rock for building purposes. As decomposition progresses the amount of interstratified sand greatly increases, and the blocks become proportionately smaller.

The *Atherton quarry* is a short distance west of the Guilford and Waltersville quarry. It was opened about eighteen months prior to the writer's examination in March, 1908, in bowlder exposures of the granite.

The rock is a biotite granite and is entirely similar in color, texture, and composition to that of the other quarries in the Woodstock area, already described. It is likewise equally suited for the various uses made of the granite from the Guilford and Waltersville quarry (p. 58).

PORT DEPOSIT AREA.

Probably the Maryland granite which is best known outside of the State is that quarried in Cecil County, near the northern limits of the town of Port Deposit, on the northeast side of Susquehanna River. The value of this granite was early recognized, and it was quarried for foundation stone for the oldest colonial dwellings. Though it was worked in a small way for many years, the quarrying industry may be said to date from the years 1816 and 1817, when stone was quarried for the bridge built across Susquehanna River.

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[a] Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 725.

The only quarries operated in this area are those of the McClenahan Granite Company, 1 mile northwest of Port Deposit, immediately on the northeast side of the Susquehanna. (See Pl. VI, *A*.) The quarries are opened in the nearly vertical granite wall (cliff) which extends for some distance along the northeast side of the river, and measures about 200 feet from the base to the top. A number of very extensive openings have been worked in the wall along the river front within a distance of 3,000 feet. The natural advantages for quarrying and shipping at this point would, indeed, be difficult to excel. The average depth of the quarry is 200 feet, with an extreme depth of 230 feet, and in one exposure it is opened to a depth of 15 feet below the river level. The depth of stripping on the surface varies from 1 to 25 feet.

The rock is a biotite granite gneiss (foliated granite) of light bluish-gray color and medium grain. Its schistose, or foliated structure, is pronounced and is highly characteristic.[a] The principal minerals are soda-lime feldspar (oligoclase), potash feldspar (orthoclase and microcline), quartz, and biotite, with accessory apatite, zircon, titanite, allanite, garnet, tourmaline, and magnetite. The secondary minerals are muscovite, hornblende, epidote, chlorite, and occasionally calcite. The quartz and feldspar occupy well-defined areas, which show crushing and recrystallization into a mosaic, as a result of the dynamic forces, which have modified the original granite. The feldspars show less perfect granulation than the quartz. Acidic plagioclase, the extinction angles of which place it between Ab_3An_1 and Ab_2An_1, so that it corresponds to oligoclase, is the dominant feldspar. The microcline has been derived, probably, in part at least, from orthoclase by pressure. The shreds of biotite are orientated and lie in approximately parallel lines, thus producing the gneissoid structure of the granite gneiss. The lines of mica shreds are not straight and continuous, but are arranged in more or less disconnected and overlapping bands.

A chemical analysis of the granite gneiss from Port Deposit is given on page 42. The analysis indicates that soda is in excess of potash, thus confirming the apparent predominance of plagioclase over orthoclase and placing the granite with the quartz monzonite type.

The course of the foliated or gneissoid structure is N. 35° E. Vertical joints strike N. 35° E., N. 60° E., N. 70° W., and north-south. Zones of close jointing occur at intervals in the direction of the N. 70° W. set, and to a less extent in the N. 35° E. set. The N. 35° E. joints show a dip of as much as 58° N., 35° W. The spacing between joints varies from a fraction of an inch up to 15 feet, and is in general sufficiently great to allow the extraction of dimension stone.

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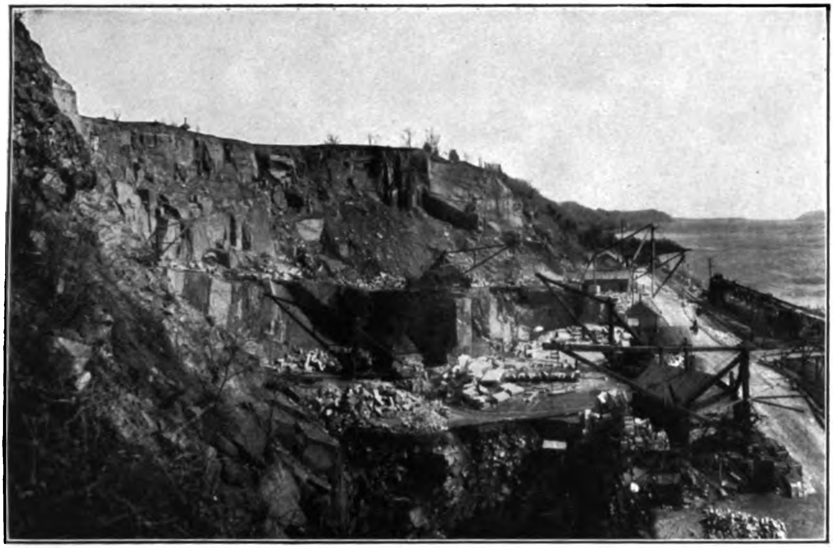
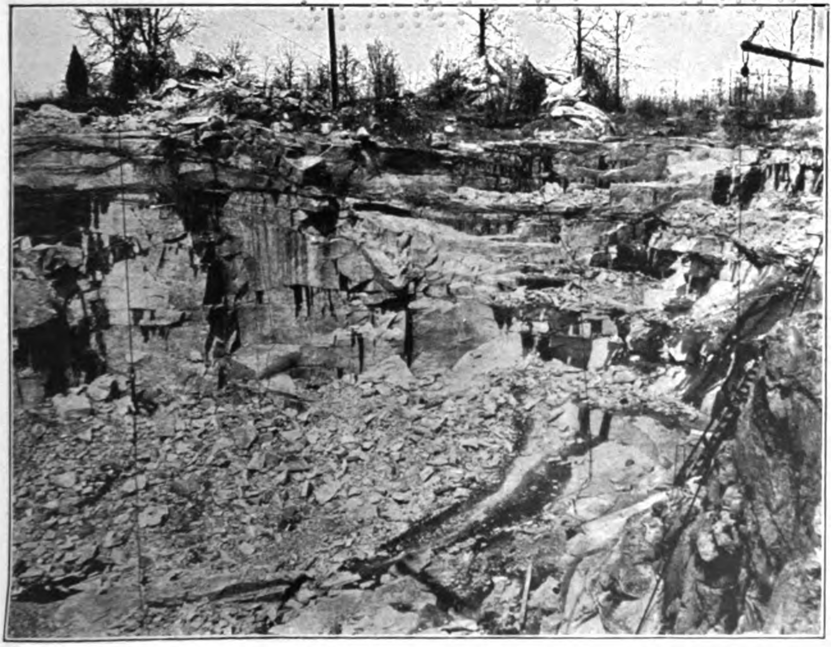
[a] For description see Maryland Geol. Survey, vol. 2, 1898, pp. 138–147; Pls. VIII, IX.



A. McCLENAHAN GRANITE COMPANY'S QUARRY, PORT DEPOSIT, MD.



B. GUILFORD AND WALTERSVILLE GRANITE COMPANY'S QUARRY, GUILFORD, MD.

Movement in the granite mass is indicated in slickensided surfaces of many of the joint planes. Pegmatite dikes were not observed, but a few narrow veins of quartz up to 6 and 12 inches wide penetrate the granite gneiss in the quarries and are more abundant in the steep, high cliffs of granite in and below the town of Port Deposit. A few dark segregations (knots) of small and large size occur.

Tests (see p. 49) of the crushing strength (over 20,000 pounds per square inch), the absorption capacity (0.19 to 0.25 per cent), and the freezing loss establish the durability of the granite gneiss under most circumstances. This is further confirmed by a study of its mineralogical and chemical composition and of the stone itself under natural conditions in the quarries.

The product of the quarries is shipped as far west as Chicago and Cincinnati and as far north as New England; but the principal market is in Pennsylvania. No shipments have been made south of Norfolk, Va. The quarries are favorably located for shipment by water and rail routes.

The principal use made of the product is for general building purposes, in both the rough and the dressed states. It is largely used for bridge and ashlar work and, as crushed stone, for various purposes, such as for ballast, macadam, and concrete, in chemical filtering, and in fertilizers.

FRENCHTOWN AREA.

Near Frenchtown, about 4 miles southeast of Port Deposit, in Cecil County, is another body of granite gneiss similarly situated. The rock is of the same general character as that quarried at Port Deposit. One quarry has been opened at the east end of the suspension bridge of the Baltimore and Ohio Railroad over the Susquehanna, on the northeast side of the river. It is reported to have been opened during the construction of the railroad bridge, but quarrying did not assume importance until 1894. The cold-storage warehouse and an extension of the Baldwin Locomotive Works in Philadelphia were built from the Frenchtown rock.

The rock is a biotite granite gneiss (foliated granite) of gray color and medium grain. It is probably a shade darker in color than the granite at Port Deposit because of the prevailingly darker color of the biotite. Its microscopical characteristics are the same as those of the granite gneiss at Port Deposit (p. 60). The chief minerals are soda-lime feldspar (oligoclase), potash feldspar (orthoclase and microcline), quartz, and biotite, with accessory apatite, zircon, and allanite. The secondary minerals are chlorite, epidote, muscovite, garnet, and kaolinite. Granulation of the quartz and feldspar into fine mosaics and orientation of the biotite along parallel lines, producing gneissoid or foliated structure, are the most characteristic dynamic modifications of the original granite. The foliated or schistose structure of the granite gneiss is not so strongly developed as in the Port Deposit rock, but the two are closely similar in color, texture, and composition.

In 1908 the dimensions of the opening were approximately 300 by 75 feet by 30 feet deep. Two prominent sets of vertical joints are developed at approximately right angles to each other, striking N. 60° E. and N. 40° W., with a wide range in dip. The surfaces of some of the joints are smooth and polished and are coated with a thin veneer of dark-greenish to yellowish micaceous material, resulting from motion in the granite mass. Horizontal joints, separating the rock into sheetlike masses of varying thickness, are most pronounced in the upper portions of the quarry. Decay is shown prominently along the vertical and horizontal joints near the surface, in the gaping of the joints and in the hydration and oxidation of the rock minerals. Scattered quartz veins striking N. 60° E. and varying in width from a fraction of an inch to 6 inches penetrate the granite gneiss. There occur, also, a few dark segregations (knots) of small dimensions.

At the time of examination in 1908 most of the product was worked into blocks for paving. It is capable, however, of a wide range of uses. Its principal markets are reported to be in Pennsylvania and Maryland. The transportation facilities are very good, and are similar to those at Port Deposit.

Other masses of similar granite gneiss (foliated granite), less favorably located for commercial purposes, occur on either side of Susquehanna River in the vicinity of Port Deposit.

MINOR GRANITE AREAS.

In addition to the five principal areas already described, there are a number of minor granite areas in the State which have been worked from time to time to supply the local demands. Of these minor areas the most important are Dorsey Run, on the Baltimore and Ohio Railroad between Ellicott City and Woodstock; Sykesville, on the Baltimore and Ohio Railroad west of Woodstock; Garrett Park and Brookville, a few miles northwest of Washington; Franklinville, on Little Gunpowder River, 3 miles north of Bradshaw; Benson, in Harford County; Baldwin station, in Cecil County; Texas, about 12 miles north of Baltimore; and Relay, 9 miles southwest of Baltimore. No quarries have been opened in the Texas and Relay areas.

DORSEY RUN AREA.

The Dorsey Run area comprises a small oval-shaped granite mass located on Patapsco River a few miles northwest of Ellicott City. It is surrounded on all sides by dark-colored Baltimore gneiss. The relations of the granite to the gneiss are well shown in a cut of the

Baltimore and Ohio Railroad 400 feet in length and 40 to 50 feet in height.[a]

The rock is a biotite granite of dark color and is massive, even grained, and homogeneous in texture. Allanite and epidote are abundant accessory constituents, and the granite is classed by Keyes as an allanite-epidote granite which differs but little from the other allanite-epidote granites of the region. Biotite is much altered to chlorite. Orthoclase, abundant plagioclase (oligoclase), and variable microcline compose the feldspathic constituent. Much of the quartz is crushed and fractured, and the feldspar is peripherally granulated from pressure metamorphism. Chemical analyses of the granite and of the lighter-colored, more acidic granite dikes, regarded as probable apophyses from the main mass, are given on page 42.

According to Mathews the granite was first used on the Baltimore and Ohio Railroad to protect it against the encroachment of Patapsco River. Several small quarries have been opened since, but had not been operated for some time prior to the writer's visit in 1908.

SYKESVILLE AREA.

The Sykesville granite area is one of the largest in the State. Except in the vicinity of Washington and for a short distance northward on the east side, the granite is entirely surrounded by the Wissahickon mica gneiss, of probable pre-Cambrian age. According to the recent map of the Maryland Geological Survey and as shown on the map accompanying this report (Pl. I), the granite is prolonged southward into Virginia.

The rock is a biotite granite of gray color and fine grain. Its principal minerals are orthoclase and plagioclase (oligoclase), quartz, and biotite. The biotite is considerably altered to chlorite and the feldspars to scales of colorless mica and kaolin. Large plates of muscovite are aboundant in some sections. Muscovite is partly secondary. A few garnets occur in several of the thin sections. Pressure effects are pronounced in the granulation of the feldspar and quartz, more especially the quartz, and as a rule the granite is more or less foliated.

A quarry opened in 1888 for paving blocks, a few hundred rods below the railway station, showed a large number of inclusions of irregular fragments of foreign rocks of all sizes and shapes incorportated in the granite. Keyes says:[b] "Among the fragments noted may be mentioned those which were originally limestone, soapstone, pyroxenite, vein quartz, hornblendic, and biotitic gneisses."

At present no quarries are in operation in the Sykesville granite area.

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[a] See Fifteenth Ann. Rpt. U. S. Geol. Survey, 1895, Pl. XXXVII, fig. 3, for a diagrammatic section of this cut.

[b] Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 726.

GARRETT PARK-BROOKVILLE AREA.

Extending westward along Potomac River and northward from Washington, in Montgomery County, Md., and the northwestern portion of the District of Columbia, are extensive areas of granitic rocks. According to Williams and Keyes the rock types have been largely derived from original granites by dynamic metamorphism and over most of the district are now more properly called granite gneisses. Extreme foliation has obliterated most of the granitic features, but the abundance of indistinct masses, which resemble inclusions, scattered through the granite gneiss in places, led Williams to assume for the rock an igneous origin. Within this large district are included the Cabin John Bridge, Murdoch Mill, Broad Branch, Garrett Park, Rock Creek, Brookville, Sligo Branch, and Piney Run localities referred to by Williams and Keyes.[a]

The principal rock type is a foliated biotite granite or granite gneiss, containing hornblende as an important constituent in some localities. The feldspar constituent comprises usually the potash varieties (orthoclase and some microcline) and the soda-lime variety (oligoclase). The biotite-bearing granite ranges from fine to medium grained in texture, and from light to dark gray in color. The typical hornblende granite is exposed for some distance along the Rockville road about 2 miles north of Garrett Park. It is of dark color and contains about equal amounts of hornblende and biotite. Analyses of the biotite type of gneiss along Potomac River, in Montgomery County, Md., are shown in columns 11 and 12 of the table on page 42, and of the foliated granite in the District of Columbia in column 13 of the same table.

The gradation of the different facies of the granitic rocks of this area into each other is stated by Williams as follows:[b]

> In the large granite area extending from Tridelphia southward to Brookville, in Montgomery County, the rock grades from a dark basic granite resembling a diorite to one which is very light colored and acid. In the Murdoch Mill granite area, west of Washington, gradual passages into a diorite facies are frequent, while the same thing takes place, with the development of still more basic varieties, in the granite area which extends southward from Falls Church, in Fairfax County, Va. The most striking example of gradual passage from one igneous type into another is, however, to be found in the wide belt which crosses the Potomac River at Cabin John Bridge. This originates near the southern portion of the Frederick sheet, above Bethesda Park, as a normal gabbro similar to that occurring near Baltimore; and as it passes southward it gradually becomes more acid, developing hornblende in the place of pyroxene, and thus merging into a diorite. Still farther south the diorite becomes biotitic, its feldspar more acid, while a little quartz commences to show itself. After the passage of the river the rock becomes a hornblende granite and, without any break in the continuity of the mass, is developed along Pimmit Run as a typical granite.

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[a] Fifteenth Ann. Rept. U. S. Geol. Survey, 1893-94 (1895), pp. 665, 669, 670-671, 729-730.

[b] Idem, p. 671.

The recently published map [a] of the Maryland Geological Survey differentiates the rock types in this region as follows: A large granite heel extending westward and northward from Washington to Sykesville, in Carroll County, Md., west of Baltimore; diorite and gabbro areas, chiefly diorite, within the granite, extending northward from the Potomac and only a short distance northwest of Washington; and a small area of Baltimore gneiss in contact with the granite on the east side and a short distance north of Washington. From the southern border of the Baltimore gneiss to Potomac River the eastern limits of the granite are concealed beneath the Coastal Plain formations, and the entire granite mass is surrounded by the Wissahickon mica gneiss on the west and north sides and for most of the distance on the east side.

A number of quarries have been operated within the area. The first was opened at Brookville about the beginning of the last century and was operated in a small way at intervals up to 1881. A second quarry was opened at Brookville in 1850. Several small quarries, opened in the granite exposures along Rock Creek at Garrett Park, have been worked at intervals to supply the local demand. Perhaps the most extensive quarry in Montgomery County was opened in 1850 near Cabin John in a schistose granite of dark-gray color. The total production of stone from this quarry was very large, the product being used principally for general building purposes, foundations, and road metal.

FRANKLINVILLE AREA.

The Franklinville granite area is located partly in the counties of Baltimore and Harford, northeast of the city of Baltimore, and is traversed in a southeastward course by Little Gunpowder River. It is partly covered by Coastal Plain sediments, and is in contact with gabbro on the south and west sides and with Baltimore gneiss on the north side. The rock is a foliated biotite granite resembling that quarried at Port Deposit, although somewhat darker and more foliated.

A quarry opened at Franklinville, on the Little Gunpowder, 3 miles north of Bradshaw, has supplied local demands. Mathews states that large curbing blocks might be obtained easily, as blocks 11 by 2 by 1 foot have been quarried.

BENSON AND BALDWIN STATION.

Mathews reports that a little granite is quarried in the town of Benson, Harford County, and near Baldwin station, Cecil County. The operations have been greatest at the latter locality, where the quarry was first opened in 1842 in a schistose granite. The writer did not visit either of these two localities.

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[a] Maryland Geol. Survey, vol. 6, 1906.

TEXAS AREA.

The Texas area, situated about 12 miles north of Baltimore, comprises an oval-shaped granite mass between 4 and 5 square miles in extent. It is surrounded chiefly by the Cockeysville marble, except at the northwest corner, where it is in contact with the Wissahickon mica gneiss. A second thin band of the gneiss extends for some distance along the margin on the east side between the granite and the marble.

The main body of the rock is a biotite granite with a distinct porphyritic facies along the western margin. It is composed of the essential minerals feldspar (including orthoclase with about equal amounts of oligoclase and microcline), quartz, and biotite. Biotite is much altered to chlorite and epidote and the feldspars to a light-colored mica. Zircon and apatite are the principal microscopic accessory minerals. Pressure effects are pronounced in the quartz and feldspar, and the rock presents, both in thin sections and in hand specimens, a distinct gneissoid appearance. The porphyritic portions of the mass along the western margin may be designated an augen gneiss.

No quarries have been opened in the Texas granite area.

RELAY AREA.

A small area of granite lies on Patapsco River in the vicinity of Relay, 9 miles southwest of Baltimore. The rock is a biotite granite of dark-gray color, rather coarse grained, more or less porphyritic in texture, and somewhat foliated from pressure metamorphism. Biotite, here and there intergrown with shreds of muscovite and considerably altered to chlorite, is orientated along parallel directions. The quartz is much crushed and fractured and the feldspar exhibits pronounced peripheral granulation. Orthoclase and some plagioclase (oligoclase) make up the feldspar content. The feldspar phenocrysts usually exhibit crystal boundaries. This granite resembles, microscopically, that quarried at Ellicott City, a short distance up the river.

GNEISSES.

INTRODUCTORY STATEMENT.

The Baltimore gneiss, mapped by the Maryland Geological Survey as extending along the eastern slope of the Piedmont in several well-defined areas between Susquehanna and Potomac rivers, is the oldest formation in the State and is of Archean age. It is described by the Maryland Survey as follows:[a]

> The easternmost of these Baltimore gneiss occurrences is within the area of Cecil County, east of the Susquehanna River, and extends from this point southwestward, widening to an area of 5 miles or more in breadth where it is overlain by Coastal Plain

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[a] Clark, W. B., and Mathews, E. B., Maryland Geol. Survey, vol. 6, 1906, pp. 106, 107.

deposits in Harford County. This formation is limited on either side by igneous rocks. A northern outlier a mile or less in width extending for several miles southwestward from the Susquehanna River probably represents a detached portion of this larger mass lying a little to the south.

The second area of Baltimore gneiss is found in an anticlinal dome, 15 miles long and 5 miles broad, lying on either side of the Northern Central Railroad 10 miles south of the Mason and Dixon line and 20 miles north of Baltimore. Three smaller areas occur in the vicinity of Baltimore. Two of these are portions of anticlinal domes which are either completely inclosed by overlying sediments or cut off by faults and igneous rocks, while the third, underlying the northwestern part of Baltimore City, is entirely surrounded by gabbro and other igneous masses and is overlain in great measure by the Coastal Plain deposits.

The rocks in each of these areas consist of highly crystalline gneisses composed of quartz, feldspar, and mica, with accessory minerals, which are so distributed as to produce well-marked, gray-banded gneisses, the individual bands of which vary from a fraction of an inch to several feet, the average thickness, however, being quite slight. Some of these bands are highly quartzose, resembling a micaceous quartzite; others are rich in biotite or hornblende, producing dark schists, which in a hand specimen are indistinguishable from metamorphosed igneous masses. Within the areas of Baltimore gneiss are also numerous small bodies of metamorphosed granites and more basic igneous rocks, which have been intruded into the gneiss and subsequently metamorphosed until they are practically indistinguishable from it.

Extensive quarries have been opened in the Baltimore gneiss and worked for very many years on the north and west sides of the city of Baltimore, grouped about two centers, Jones Falls and Gwynns Falls.

JONES FALLS QUARRIES.

The quarries on Jones Falls, at the northern limits of the city of Baltimore, were opened probably before the beginning of the last century. A published record in 1811 states that the gneiss was quarried on both sides of Jones Falls.[a] The first quarries opened, situated probably on the right bank of the stream, were worked until about 1830. The quarries opened on the left bank are reported to have been continuously operated from the date of opening until the present time. The principal quarries in operation at the time of examination in 1908 were the Atkinson, Curley-Schwind, and Peddicord.

The rock is a banded gneiss of variable color, texture, and composition. The bands range in thickness from 2 or 3 inches to 5 or 6 feet, and are usually rather uniform for considerable distances. They dip to the northwest at an angle of about 45°, but flatter and steeper dips are not uncommon. The variation in color is from very light gray to blue-black, being dependent on the amount of biotite or hornblende present. Probably a blue-gray is commonest, and this has given rise locally to the term "blue stone" among the quarrymen and in the trade. In texture the rock ranges from fine to medium grained. In many of the beds the component grains are of approximately the same size, producing a rock of uniform texture.

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[a] Mathews, E. B., op. cit., p. 162.

The gneiss is highly variable in composition, ranging from essentially a hornblende gneiss on the one hand to a biotite gneiss on the other. Both biotite and hornblende, more especially the former, are subject to wide variation in amount. In the mica-bearing gneiss, which is probably the most abundant facies, the rock may be composed almost entirely of quartz, with very little mica and feldspar, or it may be made up of quartz, feldspar, and mica (biotite) in nearly the proportions of a very acidic granite. In the hornblende-bearing facies of the gneiss the very dark, blue-black bands are composed largely of hornblende with very little feldspar or quartz. Among the secondary minerals occurring in the gneiss are epidote and garnet, less commonly fibrolite, cyanite, and staurolite. Many thin sections of the light-colored bands show the constituent grains to be somewhat rounded and not interlocked as in igneous rocks, suggesting that the gneiss is probably of sedimentary origin, and it is so regarded by the geologists of the Maryland Geological Survey.

In some quarries the rock is thoroughly decayed in places to a depth of 25 feet and more. Usually two sets of vertical joints are developed at approximately right angles to each other. Their courses are N. 30° E. and N. 40° W. The surfaces of some of the joints are slickensided, indicating movement. These quarries are well known for the large number of minerals that coat the surfaces of some of the joints (p. 32). Pegmatite dikes ranging from an inch to several feet across cut the gneiss in places. For figures of tests to determine crushing strength, absorption, and freezing loss, see pages 48, 50.

The product of these quarries is used principally in the city of Baltimore for paving and curbing, chiefly the latter, and in the form of crushed stone.

GWYNNS FALLS QUARRIES.

The quarries along Gwynns Falls, near the western limits of the city of Baltimore, were not opened for about fifty years after those along Jones Falls. Systematic work dates from about 1850 and has continued to the present time. The principal quarries in the area are the John G. Schwind quarry, on Edmondson avenue, and the Leonard quarry, a little farther west on Gwynns Falls. In addition to these two, there are a number of smaller quarries in the immediate vicinity. The rock is essentially the same in all and is closely similar to that quarried along Jones Falls. Quarrying operations extend from the dam south of Edmondson Avenue Bridge for a distance of a mile or more southward, along the west side of Gwynns Falls.

The rock is an irregular gneiss showing variations of color, texture, and composition similar to those of the gneiss quarried along Jones Falls. The general strike of the beds is N. 45° E., and the average dip is 30° NW. Much steeper dips are observed in places, resulting from irregularity of the folding. The average thickness of the beds ranges from 1 to 4 feet. In composition the rock ranges from a hornblende gneiss to a biotite gneiss, with wide variation shown in the amount of hornblende and biotite, especially the latter. The lighter-colored layers are composed essentially of quartz, much or little feldspar, and very little biotite, closely resembling a light-colored, very fine-grained granite. Some bands are more feldspathic and micaceous than others and likewise vary in the degree of lamination. The lighter beds furnish the most desirable grade of stone.

Two principal sets of vertical joints, nearly at right angles to each other, strike N. 55° E. and N. 50° W.; minor jointing is developed in other directions. The joints are spaced at intervals ranging from a few inches to several feet, but are not so close as to prevent the quarrying of dimension stone. Numerous minerals, such as laumontite, stilbite, etc., listed on page 32, are distributed along the faces of some of the joints.

Pegmatite dikes of very large dimensions intersect the gneiss in places. The principal mica in the pegmatites is the light-colored potash variety, muscovite. Abundant large and small red garnets occur in the pegmatite shown in the figure. (See Pl. III.)

Like the material already described as characteristic of the Jones Falls quarries, the product from these quarries has a wide range of uses. Some of it is reported to have been furnished for many well-known buildings in Baltimore. Part is used for foundations; much of it is worked into paving blocks; and the quarry waste is utilized in the form of crushed stone for various purposes.

OTHER GNEISS QUARRIES.

Besides the large quarries on Jones Falls and Gwynns Falls, described above, there are smaller scattered quarries in the vicinity of Baltimore which have been worked to supply a local demand. The principal ones are opened along Herring Run, near Hall Spring; at Ivy; and along the upper course of Gwynns Falls, near McDonogh. Mathews reports that the material from these quarries is similar to that obtained from those on Jones Falls and Gwynns Falls, and is used locally for paving blocks, sills, steps, and curbing. The principal use made of the product, however, is for road metal in the construction of the highways radiating from Baltimore.

CHAPTER III.

THE GRANITES OF VIRGINIA.

THE VIRGINIA PIEDMONT REGION.

The Piedmont province in Virginia, a part of the eastern crystalline area which extends southwestward from New York to north-central Alabama, stretches eastward from the Blue Ridge to the western margin of the Coastal Plain and widens southward. Lack of systematic study of the Virginia Piedmont region forbids more than a most general statement of its geology. The rocks occupying the region are the oldest in the State, and, except in the Triassic areas, they are all crystalline. Rogers mapped the crystalline rocks of the region as Archean, but more recent studies reveal the fact that a part of them are as late as Ordovician in age. The rocks comprise sedimentary and igneous masses so greatly altered through metamorphism that many of them bear but slight resemblance to the original rocks. They constitute a complex of schists, gneisses, and granites, with local areas or belts of slates, quartzites, and limestones. This complex is further intersected by intrusions of basic eruptive rocks belonging, so far as they have been studied, to the diabasic, dioritic, and gabbroic types. To the east of Danville, in the extreme southern part of the region, is an extensive area of altered andesite and acidic porphyries, and their associated pyroclastic rocks (tuffs), which extends into North Carolina and is regarded as pre-Cambrian in age.

Over the eastern, northern, central, and southern parts of the Piedmont are areas of Triassic shale, sandstone, and conglomerate. The northern and eastern areas of these rocks are extensive.

DISTRIBUTION OF THE GRANITES.

In Virginia the granites are limited to the crystalline area described above and comprise both massive and schistose types. The schistose granites (gneisses) are widely distributed throughout the Virginia crystalline area, forming one of the dominant rock types. Only a small part of this area has yet furnished first-grade quarry material, for over most of the area the granites have been rendered schistose from metamorphic action and are not desirable for use in the higher grades

of work. There are, however, many localities capable of furnishing granite of superior quality for general building and monumental purposes. The principal areas which have produced and are now producing granite of superior quality are distributed in a north-south direction along the eastern margin of the crystalline region. They include the Petersburg area, the Richmond area, and the Fredericksburg area. The granite from quarries in these areas has an established reputation and has been shipped more or less to all the States and the principal cities south of New England. In addition to these there are several minor areas capable of yielding granite suitable for general building purposes, but in none of them has the stone more than a strictly local use, and it has not been placed on the market. The location of the principal granite quarries in the State is shown on the map (Pl. VII).

SCIENTIFIC DISCUSSION.

MINERAL COMPOSITION.

Conforming with well-known granites elsewhere, the Virginia rocks are mixtures of feldspar and quartz, with biotite as a third essential component in the most important areas. Muscovite in subordinate amount usually accompanies the biotite in all the granite areas of the State, and it becomes a principal constituent in the granite of the Hazel Run area, west of Fredericksburg. Hornblende is an important constituent in only a part of the granites of the Falls Church area, southwest of Washington, and it is almost unknown in the granites of the other areas. It is essentially absent from the economically most important granites of the State.

In the unique variety of granite known as unakite, occurring in the Blue Ridge near Luray, in Page and Madison counties, and near Troutdale, in Grayson County, epidote is a principal constituent and the ferromagnesian silicates are nearly or entirely absent. The epidote is entirely a secondary mineral.

The feldspathic constituent of Virginia granites is composed of plagioclase (oligoclase), orthoclase, and microcline in variable amount. In some places microcline may equal or even exceed orthoclase in amount. One of the most striking features in the mineralogical composition of these rocks is their richness in plagioclase (oligoclase), and to a less extent in microcline. Both oligoclase and microcline, however, are subject to variation, and in a few thin sections examined their poverty was a noticeable feature. It seems probable that a part of the microcline in the Virginia rocks has developed in part from orthoclase by pressure metamorphism.

Besides the above-named minerals the granites contain apatite, zircon, titanite, magnetite, and some other minerals.

CHEMICAL COMPOSITION.

The chemical composition of the Virginia granites in the Richmond, Petersburg, and Fredericksburg areas is shown in the table of analyses below:

Chemical analyses of Virginia granites.[a]

[Wm. M. Thornton, jr., analyst.]

Constituents.	1.	2.	3.	4.	5.	6.	7.	8.
Silica (SiO_2)	72.27	71.51	71.19	70.83	69.48	69.44	69.29	68.45
Alumina (Al_2O_3)	14.30	13.82	14.01	12.70	13.95	15.46	14.07	10.00
Ferric oxide (Fe_2O_3)	1.16	1.76	1.66	2.67	2.82	1.31	2.59	5.71
Ferrous oxide (FeO)	.97	1.20	1.29	1.36	1.70	1.43	2.03	2.59
Magnesia (MgO)	.70	.80	.44	.53	1.10	1.01	1.32	3.26
Lime (CaO)	1.56	1.79	2.04	1.88	2.81	2.11	2.76	6.20
Soda (Na_2O)	3.46	3.64	3.56	3.49	3.65	3.97	2.89	1.98
Potash (K_2O)	5.00	4.63	4.45	4.83	3.45	4.25	2.87	1.18
Water (H_2O)− at 110° C	.04	.17	.04	.07	.04	.07	.06	.18
Water (H_2O)+ at 110° C	.25	.31	.33	.34	.50	.29	.37	.62
Titanium oxide (TiO_2)	.31	.33	.35	.41	.47	.48	.50	.20
Manganese oxide (MnO)	Tr.	.03	.02	.03	.03	.03	.06	.05
Carbon dioxide (CO_2)	.21	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Phosphoric acid (P_2O_5)	.02	.30	.34	.33	.49	.22	.26	.25
	100.25	100.29	99.72	99.47	100.49	100.07	99.09	100.67

[a] Watson, T. L., Bull. Virginia Geol. Survey No. 1-A, 1909, p. 81.

1. Medium-textured medium-gray biotite granite. Westham granite quarries, 4.5 miles west of Richmond, Chesterfield County.
2. Medium-textured medium-gray biotite granite. Lassiter and Petersburg Granite Company's quarries, Petersburg, Dinwiddie County.
3. Fine-grained dark blue-gray biotite granite. McGowan, Netherwood, and Donald quarries, Chesterfield County, and Mitchell & Copeland quarry, Henrico County, near Richmond.
4. Medium-coarse medium-gray biotite granite. Netherwood, State (Old Dominion), Granite Development Company, Krimm, and Middendorf quarries, Chesterfield County, near Richmond.
5. Fine-grained dark blue-gray biotite granite. Cartwright & Davis quarries, near Fredericksburg, Spottsylvania County.
6. Medium-textured medium-gray biotite granite. McIntosh quarry, Chesterfield County, 5 miles west of Richmond.
7. Medium-coarse gray biotite granite gneiss. Middendorf (Belt Line Railway) quarry, near Manchester, Chesterfield County.
8. Medium-coarse gray biotite granite gneiss. Cartwright & Davis quarries, near Fredericksburg, Spottsylvania County.

The high percentage of soda in the Virginia granites has been commented on above. Soda molecularly exceeds potash in every analysis, indicating the predominance of soda-lime feldspar over potassic feldspar, a fact which places the Virginia granites with the quartz monzonites.

KINDS OF GRANITE.

Like the granites of the southeastern Atlantic States in general, the granites of Virginia vary in structure from massive to schistose, and in texture from even granular to porphyritic. On this basis three types of rocks are distinguished: (1) Massive even-granular granites, (2) porphyritic granites, and (3) schistose granites or granite gneisses. The granite gneisses were derived from the massive granites, from which they differ principally in the pronounced schistose structure secondarily induced by dynamic metamorphism.

On the basis of mineral composition the Virginia granites are divisible into the following leading types: (1) Biotite granite, which usually carries a little muscovite in addition to the biotite, and under which a majority of the granites of the State may be grouped, including the Richmond and Petersburg areas and most of the Fredericksburg area; (2) muscovite granite, of which the Hazel Run area, 1 mile west of Fredericksburg, is the only typical representative yet known; (3) hornblende-biotite granite, represented by a part of the granites occurring southwest of Washington in the Falls Church area, Fairfax County, and near Saxe, Charlotte County; and (4) epidote granite (unakite), of which there are only two known localities, one in the Blue Ridge at Milams Gap, near Luray, in Page and Madison counties, and the other near Troutdale, in Grayson County.

In addition to these types pegmatites, coarse crystallizations of quartz and feldspar with subordinate mica, in dikelike form, abundantly penetrate the finer granites and associated crystalline rocks over much of the Piedmont region. Aplite is represented only in the granite of the Richmond area, and here principally on the western border of the Richmond basin, near Midlothian.

NATURE OF THE GRANITE OUTCROPS.

Rock decay is somewhat profound over all parts of the Piedmont region, and the rocks are generally concealed beneath a variable thickness of the loose residual material. Exposures of the moderately fresh granite, however, are by no means uncommon, and because of their favorable location and topographic relations they usually afford desirable quarry sites. These exposures lie usually along the major stream courses in the form of both high and low steep slopes bounding the streams, and on the surface they are usually of a bowldery character. This is particularly true in the stream beds, where the exposures are almost invariably made up of large and small bowlders. Outcrops of this character are strikingly developed along James, Appomattox, and Rappahannock rivers in the vicinity of Richmond, Petersburg, and Fredericksburg. In these areas the quarries have been largely opened in the steep slopes immediately facing the rivers.

On the smaller streams the exposures are low and more in the form of true ledges, which may or may not be of bowldery character. The exposures on the interstream areas are in the nature of low, flat-surfaced masses, and the extent of the exposed granite varies greatly in the outcrop. Prominent granite domes, such as Stone Mountain in Georgia and North Carolina, do not occur in the Virginia region.

EVEN-GRANULAR GRANITES.

The even-granular granites are economically the most important in Virginia. Five types are distinguished: (1) The medium-gray biotite granite of the Richmond-Petersburg area, (2) the dark blue-gray biotite granite of the Richmond-Fredericksburg area, (3) the light-gray muscovite granite of the Fredericksburg area, (4) the dark-gray hornblende-biotite granite of the Falls Church area, and (5) the yellowish-green and pink epidote granite known as unakite. The differentiation of these five types is based on certain differences which are best brought out under the individual descriptions.

MEDIUM-GRAY BIOTITE GRANITE OF THE RICHMOND-PETERSBURG AREA.

The medium-gray granite has been quarried for many years in the vicinity of Richmond and Petersburg. (For description of individual quarries, see pp. 88–106.) It extends over parts of three counties—Dinwiddie, Chesterfield, and Henrico. It is a biotite granite, in many places containing a little muscovite, and the mineral grains (anhedra) range in size from 1 to 5 millimeters. Variation in the size of the anhedra within the limits given is a noticeable feature of this type of granite in the quarries around Richmond and Petersburg. Its principal minerals are quartz, orthoclase, microcline, plagioclase near oligoclase, biotite, a little muscovite, titanite, magnetite, apatite, zircon, and rutile. The secondary minerals are chlorite, epidote, a light-colored mica, and kaolin. An important feature in the mineral composition of this granite is its large content of plagioclase, which either equals or is greater than the potash feldspar. It occurs in large, stout laths, and is always characterized by polysynthetic twinning striæ in basal sections. Extinction angles measured against the twinning striæ usually indicate a plagioclase near oligoclase. Microcline is variable in amount, and may either equal or exceed orthoclase. Twinning on the Carlsbad law is generally visible among the feldspars, both in thin sections and in hand specimens of the rock. Microperthitic intergrowths of the feldspars are seen in most of the thin sections studied. Many of the larger feldspars contain microscopic inclusions of other minerals (micropoikilitic), the inclosures consisting of quartz and other feldspars.

Rutile needles are abundant in some of the quartz. Granophyric intergrowths (mutual penetrations) of the quartz and feldspars are very abundant in the thin sections studied, indicating overlap in the period of formation of these minerals. The quartz intergrowth is not restricted to any single species of feldspar, but seems to be of about equal development in the orthoclase, microcline, and plagioclase species.

Biotite is the third essential constituent; it is deep brown and strongly pleochroic. It is distributed through the rock in single long and stout shreds and as small aggregates. This constituent is subject to some variation both in size of shred and in amount; the rock becoming, according to quantity of biotite, either lighter or darker in color. Under the microscope numerous inclusions of the older minerals are seen in the biotite, among the most important of which are zircon, apatite, and magnetite. In most of the thin sections a little primary muscovite is intimately associated with the biotite, here and there as a parallel growth; in places the two micas penetrate each other, always preserving sharp and clear-cut boundaries. Much chlorite occurs as an alteration product of the biotite. Epidote, though not abundant, is usually present in many of the sections, always as an alteration product from the interaction of the biotite and feldspars, and is associated with the biotite.

Titanite is present to a minor extent in many of the sections, mostly as irregular grains and aggregates, but in part as rhombic crystals. The tint varies from nearly colorless to reddish brown, with noticeable pleochroism in the deeper hues.

Pressure-metamorphic effects are clearly defined in all the thin sections of granite of this type. They are more strongly marked in the granite from the Petersburg portion of the area than in that from Richmond. Under the microscope the pressure effects are shown in an optical disturbance of the quartzes and feldspars, more marked in the former, in the form of a wavy or undulous extinction; in a fracturing of the quartz and feldspar, which is rather strongly developed in some of the plagioclase individuals of thin sections from the Petersburg area; and lastly in peripheral shattering or granulation of the larger quartz and feldspar individuals in the granite from the Petersburg area. Also, in several sections, biotite shreds were noticed broken across, and in still other cases the folia were markedly curved or bent.

At the Netherwood quarry, several miles west of Richmond, this granite is typically shown and in some of the largest quarried blocks dressed up during the summer of 1905 a distinct schistosity was discernible. As a rule, however, the rock from this quarry and from the Richmond area in general belonging to this type appears entirely massive. In the Petersburg part of the area the dynamic effects are the most pronounced, both in the thin sections and in the hand specimens, and a tendency toward a rough parallel arrangement of the minerals—schistosity—is shown on close examination of the rock in nearly every opening.

The State, War, and Navy Building in the city of Washington was constructed from granite of this type obtained near Richmond; and the stone, which has been extensively quarried in the vicinity of Richmond and Petersburg, is used in most of the territory south of New England for building purposes.

DARK BLUE-GRAY BIOTITE GRANITE OF THE RICHMOND-FREDERICKSBURG AREA.

The dark blue-gray granite does not differ essentially in mineral composition from the light-gray rock just described, although the two bear no resemblance to each other in hand specimens. The dark blue-gray rock is much more finely crystalline, the anhedra averaging less than 0.5 millimeter in size. The biotite is uniformly distributed through the granite in minute irregular shreds which impart the pronounced dark-blue color to the rock. Like the light-gray type this is a biotite granite containing a very little muscovite associated with the biotite. Plagioclase and microcline, in quantity and occurrence, are similar in both the dark-blue and the light-gray granites.

Microscopically the two types are unlike in the degree of pressure effects indicated. The dark blue-gray granite is entirely massive, and the only effects of pressure metamorphism discernible in the thin sections are those of undulous extinction of and local fractures in the quartz. In the Fredericksburg portion of the area the rock is a shade darker in color than most of the same type in the Richmond portion. The texture is the same for the two localities, but in the quarries near Richmond there is a perceptible variation in the depth of the blue-gray color.

The dark blue-gray granite is quarried in the vicinity of Richmond and Fredericksburg for monumental stock. Uniformity in color and texture make it a most desirable granite for this purpose.

LIGHT-GRAY MUSCOVITE GRANITE OF THE FREDERICKSBURG AREA.

Light-gray granite occurs about 1 mile west of Fredericksburg on Hazel Run. It is made up of anhedra averaging about 2 millimeters in size and is essentially a muscovite granite containing considerable biotite closely associated with the potash mica (muscovite), distributed through the rock. It somewhat resembles the light-gray biotite-bearing muscovite granite of Stone Mountain, Ga. Here and there a crystal of red garnet is observed in the rock.

The effects of dynamic metamorphism are manifested in the rock in a thinly foliated structure which is discernible only on close examination. Thin sections of the granite show quartz, orthoclase, microcline, plagioclase (oligoclase), muscovite, biotite, apatite, rutile, and zircon. Chlorite and muscovite are the principal secondary minerals. Muscovite is partly primary and partly secondary. Microcline and plagioclase are present in large amount. Intergrowths of the feldspars and of the feldspars with quartz are numerous. Micropoikilitic structure in the larger feldspar individuals is strongly marked. Partial orientation of the mica along parallel directions, an occasional bent and broken muscovite shred, fractured quartzes with wavy extinction, and the perfect granulation of the quartz-feldspar individuals are pressure effects plainly marked in the thin sections.

DARK-GRAY HORNBLENDE-BIOTITE GRANITE OF THE FALLS CHURCH AREA.

The granites in the vicinity of Falls Church, Fairfax County, are of two varieties. One is a medium to finely crystalline rock and contains dominant biotite with some muscovite as a third essential constituent, and is similar in mineral composition to the Richmond types of granite. The other, a light and dark speckled rock, is a fraction more coarsely crystalline and is a hornblende-biotite granite; except for the small granite area near Saxe (p. 112), this is the only hornblende granite yet found in the State, and its affinities somewhat closely ally it with quartz diorite. It is closely associated in the field with diorite masses on the one hand and with foliated mica granites on the other; the associated diorites are partly altered to metadiorites. Petrographically it more properly belongs with the granodiorites, differing from the diorites proper in containing more quartz and potash feldspar. Thin sections show quartz, plagioclase, orthoclase, green and brown hornblende, biotite, apatite, rutile, and the secondary minerals epidote, sericite, garnet, chlorite, and kaolin. Hornblende is one of the most abundant constituents and in places it completely incloses shreds of the biotite. Microcline does not occur. Plagioclase is probably slightly more abundant than orthoclase. Pressure effects are indicated in the optical disturbance of the quartz and feldspar in fractures crossing the quartz, in the curved and bent lamellæ of a part of the plagioclase, and in the marked distortion of the cleavage angle of the hornblende.

YELLOW-GREEN AND PINK EPIDOTE GRANITE—UNAKITE.

Unakite derives its name from the Unaka Mountains in western North Carolina and eastern Tennessee, where it was first observed.[a] Until very recently knowledge of it in Virginia was limited to a single locality—Milams Gap, in the Blue Ridge, near Luray, but it has lately been noted near Troutdale, Grayson County.[b] The mineral composition of the rock from the Virginia and North Carolina-Tennessee localities places it among the granites with epidote as an essential constituent, but according to the analysis by Phalen [c] of specimens from Milams Gap the rock is relatively basic for a granite.

The rock is a moderately coarse but irregular crystallization of red feldspar, quartz, and green epidote. Irregular crystallization of the rock is shown in its range from masses that are more than two-thirds red feldspar through all gradations to masses composed of quartz and epidote without feldspar (epidosite)[a]. Thin sections of the unakite from Milams Gap show epidote, orthoclase, quartz, iron oxides, zircon, and apatite. The epidote is secondary, replacing pyroxene and feldspar, both plagioclase and orthoclase.

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[a] Bradley, F. H., Am. Jour. Sci., 3d ser., vol. 107. 1874, pp. 519, 520.

[b] Watson, T. L., Am. Jour. Sci., 4th ser., vol. 22, 1906, p. 248.

[c] Phalen, W. C., Smithsonian Misc. Coll., vol. 45, 1904, pp. 306–316.

The unakite-bearing rock at Milams Gap is, according to Phalen, a hypersthene akerite (hypersthene-quartz-diallage syenite), a coarse-grained dark grayish-green aggregate consisting essentially of feldspars and black pyroxenes. Thin sections of the syenite reveal the following minerals: Orthoclase, plagioclase, orthorhombic and monoclinic pyroxene, quartz, microcline, iron ore, apatite, and zircon, with the alteration products epidote, chlorite, and sericite. Hornblende is essentially absent in the thin sections. Phalen regards the unakite as having originated from the akerite by hydrometamorphism aided by dynamic disturbances.

The following analyses of the unakite and the unakite-bearing rock (akerite) are quoted from Phalen (p. 313):

Analyses of unakite and akerite from Milams Gap, Virginia.

[W. C. Phalen, analyst.]

Constituents.	Unakite.	Hypersthene akerite.
SiO_2[a]	58.32	60.52
Al_2O_3	15.77	16.99
Fe_2O_3	6.56	.60
FeO	.89	6.53
MgO	.09	1.59
CaO	11.68	4.58
Na_2O	.32	2.83
K_2O	4.01	3.91
H_2O	1.73	.88
P_2O_5	.48	.74
MnO	.13	.25
Cr_2O_3	....	Trace.
ZrO_2	Trace.	Trace.
	99.98	99.42

[a] Including TiO_2.

PORPHYRITIC GRANITE.

Unlike the crystalline region of North Carolina and Georgia, Virginia contains few porphyritic granites. The best developed and most typical area in the State is that bounding the eastern margin of the Richmond coal basin near Midlothian, 13 miles west of Richmond, and extending about 20 miles in a north-south direction. It marks the western limits of the even-granular granite quarried around Richmond and Petersburg. The porphyritic and even-granular granites are both biotite granites and differ from each other only in texture.

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[a] Phalen, W. C., op. cit., p. 312.

The rock in the vicinity of Midlothian is a coarse biotite granite, the porphyritically developed mineral of which is potash feldspar. The phenocrysts are of large size, in part twinned on the Carlsbad law, as a rule idiomorphic and flat tabular in habit and are orientated in a general north-south direction from flowage of the rock. The ratio of phenocrysts to groundmass is variable. The porphyritic texture with variations is traced as far north as Gayton, Henrico County, and as far south as Winterpock, Chesterfield County. The evidence seems clear that the porphyritic granite underlies in part the eastern portion of the Richmond coal basin, but its relations to the crystalline rocks on the west can not be stated, for the line of contact is concealed beneath the cover of Newark rocks of the coal basin.

No quarries have been opened in the porphyritic granite.

GNEISSES.

INTRODUCTORY STATEMENT.

Gneisses of granitic composition make up one of the principal rock types in the Virginia Piedmont complex. Many of these gneisses were derived from original massive granites, and they are usually of the mica variety. In mineral composition the granite gneisses are essentially identical with the massive granites, except that hornblende is associated with biotite in the gneisses of the Richmond and Fredericksburg areas. In some of the thin sections hornblende is largely in excess of the biotite. The gneisses differ from the granites principally in having a banded structure, produced through pressure metamorphism. The banding may be fairly regular, but as a rule it is very irregular; in either case the rock is composed of alternating bands of light and dark minerals. The individual bands may vary much in thickness. The structural features of the rock of this type in the Virginia area render it unsuitable for use in any except the rough grades of work, and it is but little quarried in the State.

Between the entirely massive granite and the typical granite gneiss intermediate grades of schistosity are easy of differentiation over parts of the Virginia region. This undoubtedly means that in some of the areas a less schistose granite may grade into a more schistose granite. In other areas this interpretation is not possible, for the massive granites are sharply defined structurally from the schistose granites, and wherever contacts were found it was entirely clear that the massive rock was younger and had been intruded into the schistose rock.

GNEISS OF THE RICHMOND-FREDERICKSBURG AREA.

The gneiss is the oldest of the granitic rocks in the Richmond and Fredericksburg area, and it is invaded by both the medium-gray and the dark blue-gray massive granites. Figure 3 shows the relation between the dark blue-gray granite and the gneiss at the McGowan quarry south of Manchester. Similar relations prevail between the granite and the gneiss in the Cartright & Davis quarries 3 miles northwest of Fredericksburg. The period of deformation, inducing the schistose structure in the gneiss, preceded that of the intrusion of the massive granite, as shown by the fact that the massive granites cut across the schistosity of the gneiss and contain inclusions of the gneiss which preserve perfectly the gneissic structure.

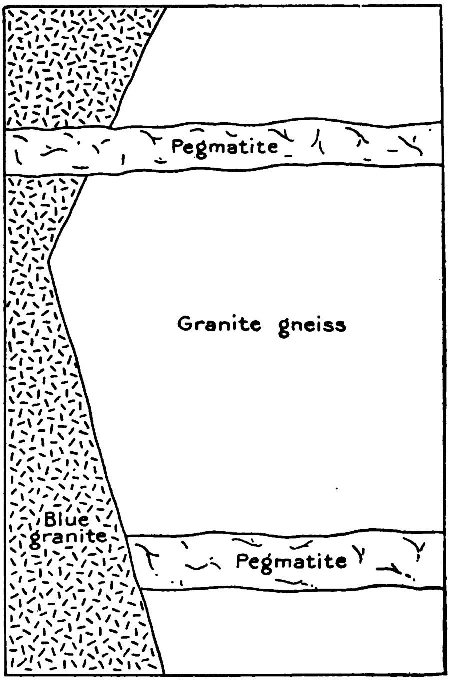
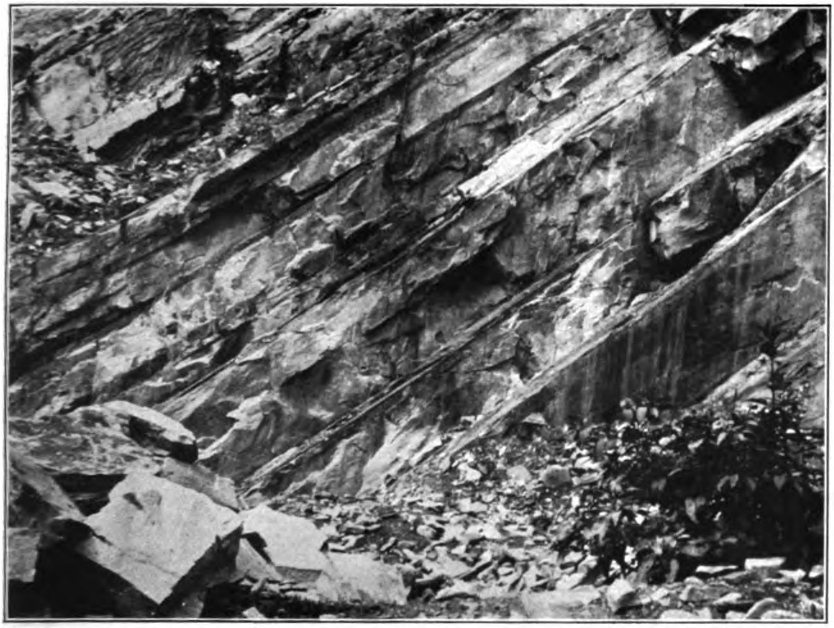


FIGURE 3.—Contact of hornblende-biotite gneiss with granite at McGowan quarry, south of Manchester, Va.

The gneiss is a hornblende-biotite gneiss of medium-coarse texture and irregular banding. It is much coarser in texture than the granites and consists of irregular alternating bands of essentially the dark and light minerals. Its principal minerals are quartz, orthoclase, plagioclase, hornblende, and biotite, with accessory titanite and apatite. Chlorite occurs as an alteration product from biotite.

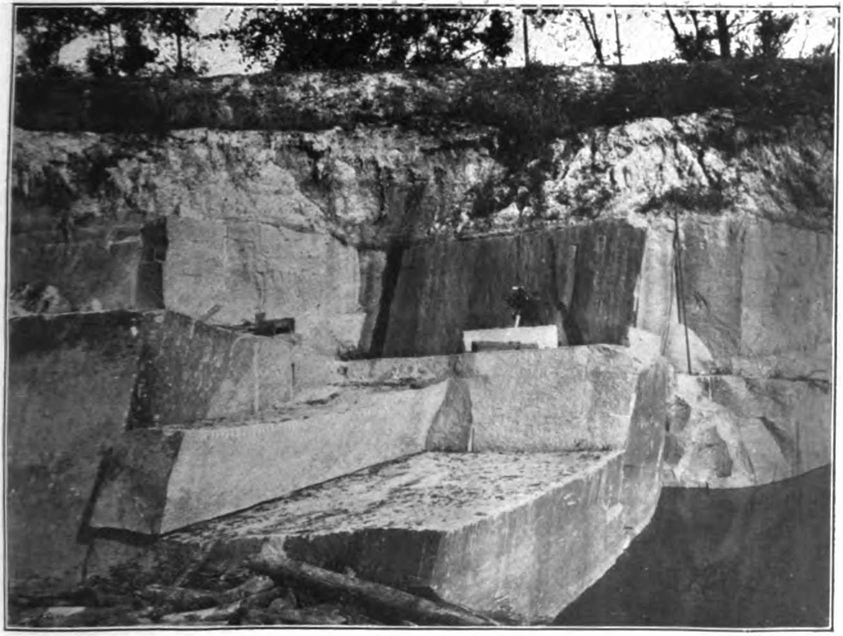
A thin section of one of the dark bands showed a preponderance of brown and green hornblende with less black mica (biotite), largely altered to chlorite. Some potash feldspar (orthoclase) and soda-lime feldspar (oligoclase), quartz, and much titanite were present. Microcline does not occur. The principal accessory minerals noted in the granite are also present in the gneiss.

Thin sections of one of the coarse-textured, light-colored bands of the gneiss showed the minerals to be quartz, potash feldspar (orthoclase) and soda-lime feldspar in nearly equal amounts, a little black mica (biotite), and several pieces of nearly colorless hornblende. Microcline is not present.



A. GNEISS QUARRY NEAR LYNCHBURG, VA.

Showing regular banding of the gneiss.



B. COOK QUARRY, NEAR PETERSBURG, VA.

Photograph by H. Ries.

The gneiss, which is older than the granite, differs essentially from the latter in having a banded or schistose structure; in the presence of hornblende, which exceeds biotite in amount in some of the thin sections; in the absence of microcline—a mineral always present in the massive granites; and in coarseness of texture. It is unsuited for the higher grades of work for which granite is used, but for other uses it will probably serve equally well. Though good quarry sites are procurable, the gneiss has not been quarried.

GNEISS OF LYNCHBURG, VA.

Extending from the north and east limits of the city of Lynchburg is an extensive body of gneiss cut across by James River and lying partly in Amherst County and partly in Campbell County. Its limits are unknown. Excellent exposures are found along James River and some of its tributaries near the city. Numerous quarries have been opened and the product is used for general building and street purposes in Lynchburg. The quarries are located along the north side of the James, in Amherst County, opposite Lynchburg, where the river has cut directly across a broad anticline of the gneiss; and to the southeast of Lynchburg, in Campbell County, along the tributaries of the James.

The rock is a biotite gneiss of dark blue-gray color and fine grain. It is of doubtful origin, and in places appears to be composed of alternating layers of gneiss and schist of a prevailing gray color. Quartz and mica are the predominant minerals in the schist. The gneiss splits readily into slabs, is hard but easily dressed, and is very resistant to atmospheric agents.

The quarries opened about 1 mile south of Lynchburg are located in beds forming the southeastern limb of the anticline. The gneissic bands are very regular and even as a rule, vary in thickness from 6 inches to several feet, and dip 45° S. (See Pl. VIII, *A*.) They are cut by a well-developed system of joints striking N. 5°–10° W. Pegmatite dikes, composed in essential part of pink feldspar with some quartz, are in places developed parallel to the banding. Along the planes of banding very thin, finely crinkled laminæ of sericite mica, in part chloritic, occur locally.

GNEISSES OF FAIRFAX AND ALEXANDRIA COUNTIES.

Extending southward from Potomac River and covering much of Fairfax and Alexandria counties are two extensive belts of gneiss, of which one is a metamorphosed granite and the other is of doubtful origin. The former, granite gneiss, is of fairly uniform color and texture; the latter is rather irregular in color, texture, and composition.

The granite gneiss has been quarried from time to time for local use from the ledges along and on the south side of the Potomac. When fresh the rock is a dark bluish-gray gneiss of rather fine grained, uniform texture. The principal minerals are quartz, orthoclase, plagioclase, muscovite, and biotite, with small amounts of garnet, chlorite, hornblende, tourmaline, and pyrite.

The gneiss of doubtful origin, designated by Keith the Carolina gneiss, is composed of alternating layers of gneiss and schist of a prevailing gray color, dark bluish gray when fresh. The bands vary in thickness. Quartz and mica are the predominant minerals in the schist; quartz, feldspar, and mica in the gneiss. So far as the writer is aware the Carolina gneiss has not been quarried in this area.

OTHER GNEISS AREAS.

Gneiss has been quarried also in Fluvanna, Bedford, Franklin, and Pittsylvania counties. These are feldspar-quartz-mica gneisses. The Virginia gneisses are usually well adapted to the rougher grades of work, such as for certain kinds of street work, for concreting and ballast, for retaining walls and foundations, and for road material. Where quarries have thus far been opened, the product has been used strictly for local purposes.

STRUCTURAL RELATIONS IN THE RICHMOND-FREDERICKSBURG AREA.

GENERAL STATEMENT.

Three types of rocks of granitic composition are represented in the Richmond area; two are massive granites; the third is a schistose granite or granite gneiss. The two massive granites are designated the medium-gray granite and the dark blue-gray granite. Three periods of intrusion are represented, in the following order, beginning with the earliest: (1) The granite gneiss; (2) the medium-gray granite; and (3) the dark blue-gray granite. This succession is plainly indicated in the field.

CONTACTS.

The numerous quarries worked in the vicinity of Richmond afford excellent opportunity for studying the contacts between the fresh granites of the three types named above. As noted in the descriptions of the three types (p. 80), the differences in color, texture, and structure render them easy of differentiation. Not one of the large number of contacts examined has shown the presence of contact minerals. Several of the contacts show inclosures of the older granite in the newer one. At one of the contacts between the medium-gray and the dark blue-gray granites in the Netherwood quarry the younger or dark blue-gray granite contains numerous irregular fragments of varying size of the medium-gray granite, as shown in figure 4. Other exposures in the same quarry reveal the true relations of the two granites. As shown in figure 5 the dark blue-gray granite invades the gray granite in two separate, nearly vertical dikelike arms.

The same relation of these two types is equally well shown in the dark blue-gray granite penetrating the medium-gray granite in the Philadelphia quarries, at the head of the settling basin, near Richmond (fig. 13).

At the McGowan quarry, several miles south of Richmond (fig. 3), and at the Cartwright & Davis quarries (fig. 14), 3 miles north of Fredericksburg, contacts between granite gneiss and dark blue-gray granite are beautifully shown. At both places the granite cuts directly across the schistosity of the gneiss.

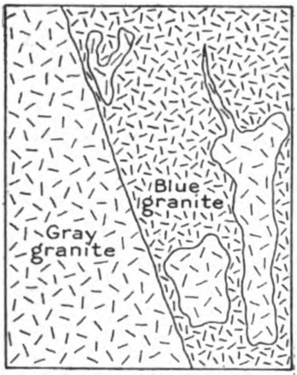


FIGURE 4.—Contact between blue and gray granites at Netherwood quarry, near Richmond, Va., showing inclusions of the gray in the blue.

APOPHYSES.

At the Cartwright & Davis quarries, 3 miles north of Fredericksburg, the sloping floor of the granite gneiss in one of the openings contains numerous large and small dikes or tongues of the dark blue-gray granite penetrating the gneiss (fig. 14). These have the texture, color, and composition of the parent mass, and they conform in part with the schistosity of the inclosing gneiss and in part cut directly across it. Similar conditions exist at the McGowan quarry, several miles south of Richmond. The Fredericksburg quarries furnish the best illustration of granite tongues penetrating from the parent mass into the inclosing rock.

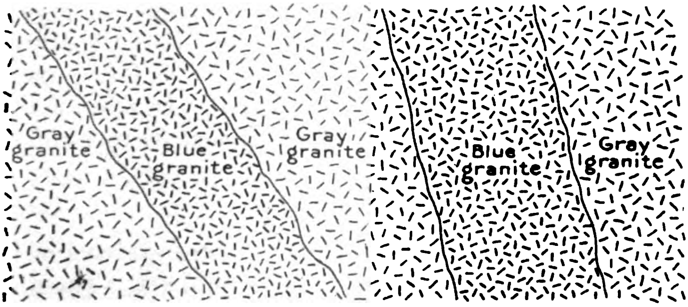


FIGURE 5.—Relations of blue to gray granite, as shown at Netherwood quarry, near Richmond, Va.

INCLUSIONS.

The inclusions correspond, in composition and otherwise, with the inclosing rock and plainly represent fragments of the country rock torn off during the intrusion of the granite containing them. In the Richmond-Fredericksburg area the dark blue-gray granite in some of the quarries contains inclusions of the massive light-gray granite (fig. 4) and of the gneiss (Pl. XII, *B*). The foliation of the gneiss inclusions is entirely preserved. No appreciable metamorphism was observable at the contacts of the inclosing granite and the inclusions.

BASIC SEGREGATIONS (KNOTS).

Dark-gray or black segregations of the iron-magnesian minerals principally, biotite usually, and less quartz and feldspar have scant development in the more productive granite areas of Virginia. The composition of the knots corresponds entirely with that of the inclosing granite, except that biotite is very largely in excess. The granites of Richmond, Petersburg, and Fredericksburg show comparative freedom from knots. Where observed in the quarries around these cities the knots were invariably of small size, usually an inch or less in diameter, and oval. A stronger tendency toward the formation of minute segregations of biotite is shown in the dark blue-gray granite near Fredericksburg than in the granite around Richmond and Petersburg.

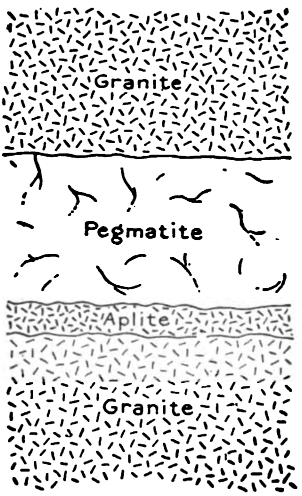


FIGURE 6.—Banded aplite-pegmatite dike in blue granite at McGowan quarry, south of Richmond, Va.

In the hornblende-biotite granite and the diorite of the Falls Church area, in Fairfax County, both large and small, nearly black, oval-shaped knots are common. In some of the undeveloped exposures of the rock the knots are so numerous and so large as to disfigure the stone.

JOINTS.

The Virginia granites are intersected by three systems of joints—a vertical set, a diagonal set, and a horizontal set. These may be widely or closely spaced. Usually the spacing is sufficiently wide to admit of dimension stone being quarried. The vertical set of joints is in general more strongly developed than the diagonal; some of the granite masses are cut by both sets.

Measurements of the joint courses made in the quarries can be summarized as follows: Two sets of joints whose planes lie in the northeast and southwest quadrants compose the major jointing, and the minor sets strike east-west and north-south. The strike of the joint planes in the northeast and northwest quadrants shows the limits of variation to be N. 5° E. or W. to N. 80° E. or W. Only a few of the planes strike east-west and north-south.

The inclined joints are less abundant than the vertical ones, and they dip at angles varying from 20° to 82°. The dips are toward the northeast, east, southeast, northwest, and southwest. Plates X, *A*, *B*, and XI, *A*, show the two systems of vertical and inclined joints. Some movement in the granite masses since the formation of the joints is indicated in the development of slickensides on the joint surfaces. Polished and striated surfaces are fairly abundant.

As a rule, joints approximating horizontality in position are strongly developed in the granites of Virginia. Probably the most noteworthy exception is the granite exposed in the quarry of the Richmond Granite Quarrying Company, where vertical jointing is well developed but horizontal jointing is not apparent. The thickness of the sheets produced by this set of joints varies greatly, ranging from 6 inches to several feet. Ordinarily the planes separate the granite into thinner sheets at or near the surface and into thicker sheets at greater depth. (See Pl. XI, *B*.)

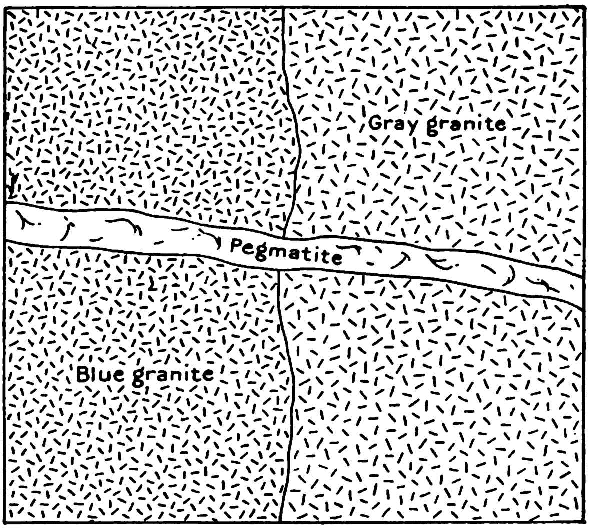


FIGURE 7.—Contact between blue and gray granites, showing pegmatite cutting both, at Netherwood quarry, west of Richmond, Va.

DIKES.

APLITES.

Aplites are uncommon in the Virginia granite areas, and have been noted by the writer only in the Richmond area. A banded aplite-pegmatite dike of small dimensions, shown in figure 6, penetrates the dark blue-gray granite of the McGowan quarry, south of Richmond. In the vicinity of Midlothian, 13 miles west of Richmond, the porphyritic biotite granite is cut by a number of small aplite dikes. Where these have been observed they are plainly of an intrusive nature, cutting the granite proper and not the inclosing gneisses.

PEGMATITES.

Pegmatites are abundantly developed in the Richmond-Fredericksburg areas, and some of them are of large size. Only in one or two places do they seriously interfere with quarrying operations. They are of granitic composition and no unusual or rare minerals have been noted in them; they cut alike the granites and gneisses. They have been worked to a moderate extent in several places in the Richmond area, but they have not yet become of economic importance.

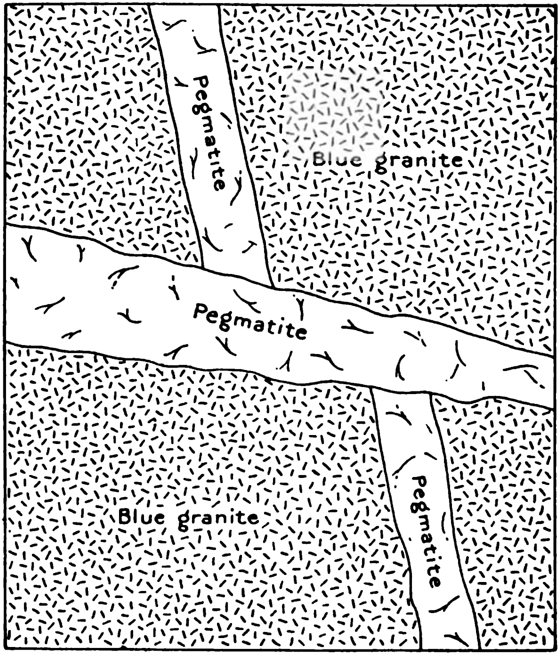


FIGURE 8.—Faulted pegmatite intersecting blue granite at Donald quarry, near Richmond, Va.

The pegmatites consist of coarse aggregates of feldspar and quartz with more or less black biotite and a little muscovite. In the Fredericksburg quarries of dark blue-gray granite, where the pegmatites are particularly abundant, massive granular magnetite and large and small perfect red crystals of garnet are not uncommon constituents. The dodecahedron and trapezohedron are the commonest forms of the garnet. The feldspar exhibits a variety of colors from opaque white and pink to a decided medium green, the former two being the prevailing shades. An acidic plagioclase is present in some of these dikes.

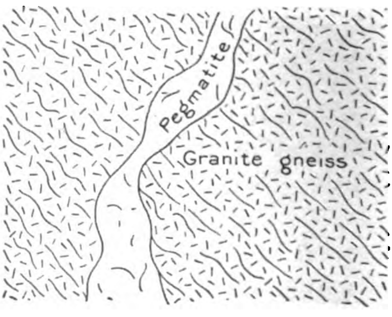
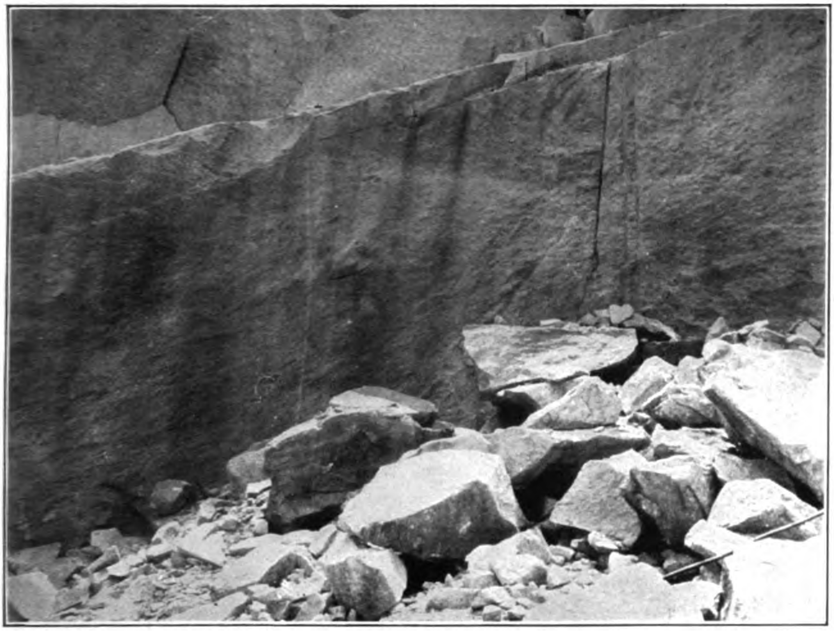


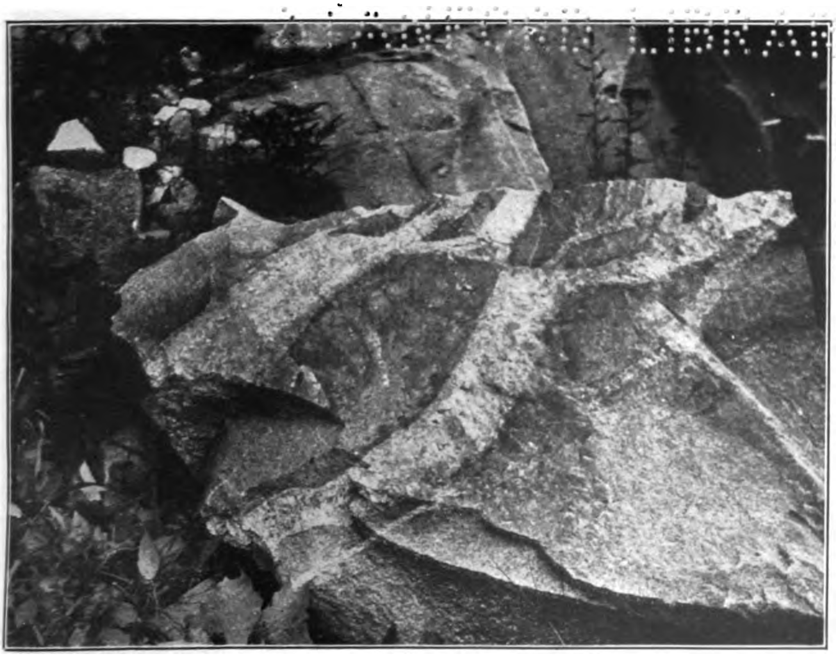
FIGURE 9.—Pegmatite cutting across schistosity of granite gneiss at Middendorf quarry, west of Manchester, Va.

The numerous quarries in the Richmond area afford excellent opportunity for studying the pegmatites and some interesting data bearing on their comparative age relations have been obtained. It



A. MONUMENTAL GRANITE, DONALD QUARRY, NEAR RICHMOND, VA.

Photograph by H. Ries.



B. PEGMATITE DIKES CUTTING GRANITE, DONALD QUARRY, NEAR RICHMOND, VA.

Photograph by H. Ries.

has been shown above that there are three granites, including the granite gneiss, in this area, representing as many periods of intrusion. The order of these intrusions, beginning with the oldest, has been shown to be (1) granite gneiss, (2) light-gray granite, and (3) dark blue-gray granite. As shown in figures 3, 7, and 10, the granite of each intrusion was accompanied by the formation of pegmatitic material. Some of the pegmatites intersecting the dark blue-gray granite, the latest of the granite intrusions, also penetrate the light-gray granite and, locally, the earliest of the intrusions, granite gneiss. These conditions are well illustrated in figures 3 and 7, which show the latest formed pegmatites intersecting the dark blue-gray granite, the light-gray granite, and the granite gneiss. Figure 3 shows a pegmatite associated with the earliest granite (granite gneiss), abruptly cut off by the intrusion of the later dark blue-gray granite into the granite gneiss. Those pegmatites which are characteristically associated with the dark blue-gray granite intersect one another in such manner as to indicate earlier and later formation. Figure 8, which shows this feature, also shows that the older or intersected pegmatite is faulted along the younger or intersecting pegmatite.

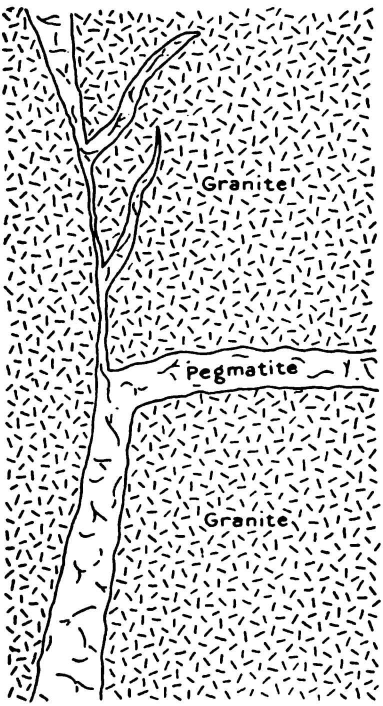


FIGURE 10.—Pegmatites showing irregularities of outline and width at Richmond Granite Quarrying Company's quarry, 4½ miles north of Richmond, Va.

The pegmatites that intersect the granite gneiss may coincide with the schistosity, as in figure 3, or may cut across the schistosity, as in figure 9. Figure 10, sketched from a portion of the Richmond Granite Quarrying Company's quarry, illustrates the irregularities of form and width of many of the pegmatites. Plate IX, *B*, shows pegmatite cutting the dark blue-gray granite in a quarry near Richmond.

Where observed the pegmatites are sharply defined from the inclosing rock; they show no banding parallel to the walls; their composition is essentially similar to that of the inclosing granite; and they are massive without evidence of pressure metamorphism.

This massive character has an important bearing on the question of the relative periods of formation of the pegmatites and the granite gneiss which they intersect. If the gneiss represents an original massive granite, which seems reasonably sure, it must follow that the massive pegmatites which characterize it were formed after the period of deformation which induced the banded or schistose structure in the gneiss. Again, this series of pegmatites must have formed prior to the periods of intrusion of the light-gray and the dark blue-gray granites, as shown in figure 3.

Pegmatite dikes assume large dimensions in many of the Virginia Piedmont counties. The economic value of these bodies has been proved in Amelia, Bedford, Hanover, Henry, and Nelson counties. As indicated in the analyses below, the feldspar of the Virginia pegmatite dikes is, with one exception, potassic.

Analyses of feldspar from Virginia pegmatites.

	1.	2.	3.	4.
Silica (SiO_2)	64.12	65.37	67.06	63.25
Alumina (Al_2O_3)	16.84	18.74	21.72	20.33
Iron oxide (Fe_2O_3)	2.28	.13		
Magnesia (MgO)	.32		.03	
Lime (CaO)	.26	.27	1.59	
Soda (Na_2O)	1.88	2.49	10.01	1.35
Potash (K_2O)	13.34	12.98	.38	12.85
	99.04	99.98	100.79	97.78
Specific gravity	2.564	2.501	2.618	

1. Potash feldspar from pegmatite dike near Amelia Court-house, Va.; C. C. Page, analyst.
2. Potash feldspar from pegmatite dike near Amelia Court-house, Va.; E. B. Sloan, analyst.
3. Albite feldspar from pegmatite dike near Amelia Court-house, Va.; R. Robertson, analyst.
4. Potash feldspar from pegmatite dike near Bells, Bedford County, Va.; Golding Sons Co., analyst.

INDIVIDUAL QUARRY AREAS.

PETERSBURG AREA.

GENERAL STATEMENT.

The Petersburg granite area includes the extreme northeastern portion of Dinwiddie County and the contiguous southeast corner of Chesterfield County. The area is crossed by Appomattox River near Petersburg, and quarries are operated to the north and south of the stream. The principal quarries, shown on the map (Pl. VII), include the Lassiter and Petersburg Granite Company's quarries, on the west side of Petersburg, and the Cook quarry, on the north side.

The granite of this area, as shown in the quarries, varies in texture from fine to medium, and in color from light to medium gray. It is a biotite granite and a little muscovite is usually associated with the biotite in variable amount. Thin sections of granite from the individual quarries show some variation in the ratio of the mineral constituents, more especially that of biotite to muscovite, and that of the different species of feldspar. In descending order the principal minerals are potash feldspar (orthoclase and variable microcline), soda-lime feldspar (oligoclase), quartz, biotite, and muscovite, with accessory magnetite, titanite, apatite, and zircon, and secondary chlorite, white mica, and epidote. An occasional grain of pyrite is observed in some of the sections, but in such minute quantity as to be entirely negligible as a deleterious constituent in the rock.

Plagioclase (soda-lime feldspar) may equal or in places exceed orthoclase (potash feldspar) in amount. Excess plagioclase over potash feldspar is indicated in some of the thin sections cut from specimens of granite from the Cook quarry. Microcline varies greatly in amount, but is usually subordinate to both orthoclase and plagioclase. Intergrowths of the different feldspars with one another and of quartz with feldspar and twinning of the feldspars on the Carlsbad and albite laws are common microstructures to all the thin sections. Biotite, partly altered to chlorite, is subject to some variation, both in size of shred and in amount, the rock being, according to the proportion of biotite, either lighter or darker in color. The granite from the Cook quarry contains less biotite than that from other quarries in the area, and is accordingly lighter in color. The effects of pressure metamorphism, shown principally in the peripheral granulation of the quartz and feldspar, occasional bent and fractured plagioclase, undulous extinction and fracturing of the quartz, and a tendency toward orientation of the minerals, especially mica, are rather strongly indicated in the thin sections of the granite from this area.

The stone from the quarries in the Petersburg area is of excellent quality and is used for monuments, general building, and street work. It is of homogeneous texture and good permanent color, and contains no harmful mineral. The joint planes are widely spaced, readily permitting the quarrying of dimension stone.

DESCRIPTIONS OF QUARRIES.

The *Cook quarry* is located about 2 miles north of Petersburg, immediately on the west side of the Seaboard Air Line Railway, within 300 feet of the crossing of this road by the Belt Line. Some stone was quarried as early as 1837, but extensive quarrying was not begun until 1887. Pl. VIII, *B*, shows a view in the quarry.

The rock is a biotite granite of light-grayish color and medium-fine, even grain. It consists of potash feldspar (orthoclase and microcline) and soda-lime feldspar (oligoclase) in nearly equal amount (the oligoclase exceeding the potash feldspars in one section), quartz, and black mica (biotite), associated with a sprinkle of white mica (muscovite), together with accessory magnetite and titanite, and secondary chlorite and epidote. Biotite is present in smaller amount than in the granite of other quarries in this area, and the color of the rock is correspondingly lighter. Pressure effects are manifest in peripheral mashing or granulation of the quartz and feldspars.

The sheets at this quarry average from 2 to 9 feet in thickness and are approximately horizontal. Pegmatites do not occur. Joints in a small exposure above the quarry strike N. 30° to 50° E. In the main quarry opening the joints strike N. 50° to 70° E. and N. 10° to 55° W., and vary in dip from vertical to as much as 65°. The sap does not exceed 4 to 6 inches in thickness. In places oxidation along joint surfaces extends to the depth of working.

The granite is admirably adapted to the uses made of it, which comprise general building purposes; street work of all forms, including blocks, curbing, and crushed stone; and wall, bridge, and culvert work in the rough and dressed state. A crusher is operated at the quarry for working up the quarry waste, mainly for concrete work. The largest-size waste is made into paving blocks, the second into rubble paving, and the balance is crushed for concrete. The product is shipped as far north as New York and as far west as Cincinnati, but practically no shipments are made south of Virginia.

The *Lassiter quarries*, comprising three or four openings made close together, are located about 1½ miles west of Petersburg, immediately on the line of the Virginia Passenger and Power Company, within a quarter of a mile of the Seaboard Air Line Railway. Some stone is reported to have been quarried here more than fifty years ago. During the summer of 1906 two of the openings were being operated by separate parties.

The rock is a biotite granite of medium dark-gray color and medium fine grain. The feldspar has a decided pinkish cast. The minerals, in descending order of abundance, are feldspar (the potash varieties, orthoclase and microcline, and the soda-lime variety, oligoclase, the latter in amount but slightly less than orthoclase and microcline), quartz, black and white micas (biotite and muscovite), with accessory titanite, magnetite, apatite, and zircon and secondary chlorite and epidote. Crushing effects are strongly marked in peripheral granulation of the quartz and feldspar and in occasional bent and fractured plagioclase individuals. Thin sections of the sap (partly decayed granite) show a somewhat advanced stage of decay in the principal minerals, which are extensively discolored by yellow iron oxide liberated from the iron-bearing minerals.

Joints intersecting the granite in the Walsh opening strike N. 70° to 80° E., N. 15° to 30° W., and east-west, and dip 70° S. The joint surfaces are slickensided from subsequent movement and are coated with a greenish altered mica. Joints measured in one of the other openings strike N. 70° E. and N. 20° to 70° W. and dip from vertical to about 80° ESE. Pegmatite dikes, from 1 inch to 5 or 6 inches wide, composed mostly of pinkish feldspar and less quartz, with little or no mica, intersect the granite. These are not so abundant as to interfere with quarrying. The joints are usually widely spaced, and blocks of granite 20 feet and more in length are frequently quarried. The depth of stripping necessary will average about 5 feet, being greater in some places and less in others. The partly decayed granite (sap) is likewise variable in thickness and will probably average several inches.

The granite works well under the hammer and is susceptible of a high polish. It is extensively used in the monument and building trades, principally in the former. The quarry waste is broken up and used for rubble. As monumental stock this granite is used in Virginia and adjoining States and as far west as Denver, Colo., and as far north as Pennsylvania and New Jersey.

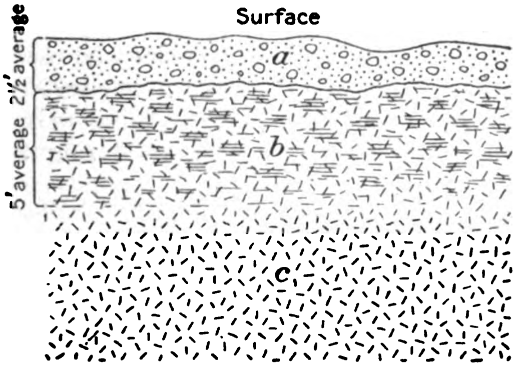


FIGURE 11.—Section at the Petersburg Granite Company's quarry No. 2, 2 miles west of Petersburg, Va.

The *Petersburg Granite Company's quarries*, comprising two principal openings about three-quarters of a mile apart, are located about 2 miles west of Petersburg and about half a mile west of the Lassiter quarry, immediately along the line of the Petersburg Passenger and Power Company. The two openings are designated No. 1, known as the Asylum quarry, and No. 2, known as the Dibble quarry. About 5 feet of stripping, comprising sand, gravel, and decayed granite, must be removed before the quarrying of fresh granite can begin (fig. 11). The openings are large and are made in flat surface exposures of the granite.

The rock is a biotite granite of medium texture and medium-gray color. It consists, in order of abundance, of potash and soda-lime feldspars (orthoclase, variable microcline, and much oligoclase), quartz, black and white mica (biotite and muscovite), with accessory magnetite, titanite, apatite, and zircon and secondary chlorite, epidote, and muscovite. Muscovite is closely associated with the biotite and is partly primary and partly secondary. Intergrowths of the feldspars with each other and of feldspar with quartz are numerous. Pressure effects are plainly marked in the thin sections, in the way common in the granite of the other quarries in this area, as already described.

Pegmatites occur only here and there and are of slight dimensions. The best-developed joints and the only ones measured strike N. 10° to 25° W. and dip from 55° to vertical. A few very small segregations (knots) of black mica (biotite) were observed in the granite. True sheeting does not occur, and the stone appears in the quarry in nearly massive form. The joints are widely spaced, and dimension stone of almost any size is obtainable.

During the summer of 1906 quarry No. 1 was being operated under lease by a Baltimore firm (Guilford and Waltersville Granite Company), and the stone used almost exclusively for building purposes in Petersburg. Some of it is used for coping in cemetery work. Quarry No. 2 has not been worked for six years or more. A large quantity of the granite has been quarried and used for various purposes.

The *Petersburg Passenger Company's quarry*, located at the dam across Appomattox River, 7 miles west of Petersburg, was opened and operated for local purposes during the summer of 1905.

RICHMOND AREA.

GENERAL STATEMENT.

The Richmond granite area, including parts of Chesterfield and Henrico counties, in the immediate vicinity of the cities of Richmond and Manchester, is the largest producing area in the State. Figure 12, a generalized section about 15 miles long through Richmond and Midlothian, shows the relations of the granite to the Coastal Plain formations on the east and to the Newark rocks of the Richmond coal basin on the west.

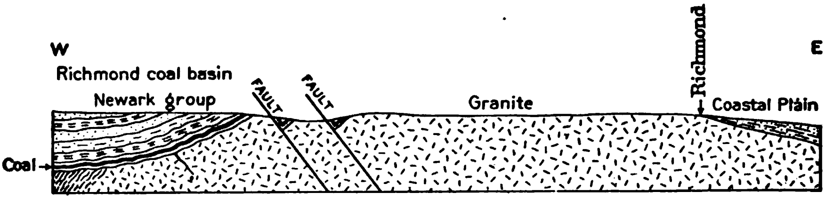


FIGURE 12.—Section from Richmond west to Midlothian, Va., and beyond.

The quarrying of granite in this area began in the early part of the last century, and a large number of quarries have been opened and worked since that time. The quarries are opened chiefly in the granite bluffs along James River, extending in a general westerly direction from the city of Richmond for a distance of more than 5 miles. Quarries have been opened to a smaller extent north and south of Richmond, in the low granite ledges exposed along the smaller streams and in flat-surface exposures on the interstream areas. Many of the quarries are very extensive and have been worked to a depth of nearly 200 feet. In some of these the depth reached in quarrying is below the river level. The quarries are well located with reference to transportation facilities and admit of easy working.

The location of this granite area, at the head of navigation on James River, affords water transportation either north or south.

KINDS OF GRANITE.

Mineralogically, the granites of the Richmond area are mica granites, but on a textural and color basis two kinds are distinguishable—a medium-grained light-gray granite and a fine-grained dark blue-gray granite. This distinction is recognized commercially, and accordingly two grades of the stone are quarried, each differing in the principal use made of it. The coarser-textured light-gray granite, elsewhere described by the writer as the Richmond-Petersburg light-gray granite,[a] is admirably suited for general building purposes. The finer-textured dark blue-gray granite, described as the Richmond-Fredericksburg dark-blue granite,[b] is extensively used for monument stock. (See Pl. IX, *A*.) Both are homogeneous even-granular granites possessing good working qualities.

The coarser light-gray granite is the older of the two and is penetrated in several of the quarries by dikelike masses of the finer dark blue-gray granite. Figures 4, 5, and 7 show the structural relations between the two granites as exposed in the Netherwood quarry west of Richmond.

STRUCTURAL FEATURES.

The structural relations of the two granites in the Richmond area have been stated above. Both granites are intruded into an irregularly banded hornblende-bearing biotite gneiss of granitic composition.

Joint structure and pegmatite dikes are well developed in the granites of this area. Each of these structures is described in some detail on pages 84–88. The joint planes are usually spaced sufficiently far apart to permit the quarrying of stone of almost any size, and the pegmatites are rarely numerous enough to cause waste in quarrying.

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[a] Bull. Geol. Soc. America, vol. 17, 1906, pp. 526–528.

[b] Idem, pp. 528–529.

MINERAL COMPOSITION.

The two types of granite distinguished above do not differ essentially in mineral composition, although they bear little or no resemblance to each other in the hand specimens. Both are biotite granites, locally containing a little muscovite. The coarser light-gray type consists of anhedra which range in size from 1 to 5 millimeters. Variation in the size of anhedra here given is a noticeable feature in the rock of this type in the quarries opened around Richmond and Petersburg. The dark blue-gray granite is more finely crystalline and its anhedra are more uniform in size, averaging less than 0.5 millimeter.

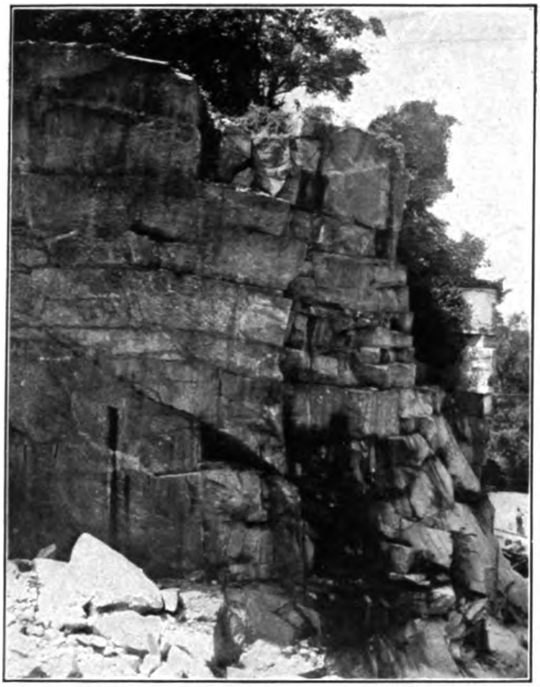
The principal minerals in the two types are orthoclase, microcline, plagioclase near oligoclase, quartz, biotite, a little muscovite, titanite, magnetite, apatite, and zircon. The usual alteration minerals occur, chief among which are chlorite, muscovite, and kaolin. Quartz and either of the feldspars present are frequently intergrown in granophyric structure. Microcline or plagioclase may either equal or exceed orthoclase in amount. These granites usually contain much plagioclase, which occurs in large, short laths and is characterized by the twinning striæ in basal sections. Extinction angles measured against the twinning striæ usually indicate a plagioclase near oligoclase. Twinning on the Carlsbad law is common among the feldspars, both in thin sections and in hand specimens.

Biotite, the third essential constituent, is brown in color and strongly pleochroic. Its distribution in the fine-grained, dark blue-gray granite is probably more uniform than in the light-gray rock, and in the latter it is subject to some variation, both in size of shred and in amount. In both types a little primary muscovite is as a rule intimately associated with the biotite, locally as parallel growths; and in places the two micas penetrate each other, always preserving sharp and clear-cut boundaries. Chlorite occurs as an alteration product of the biotite. Epidote is not abundant but appears in many of the sections as an alteration product from the interaction of the biotite and the feldspars; it is usually associated with the biotite.

The remaining minerals occur only in very subordinate amount and present no special interest.

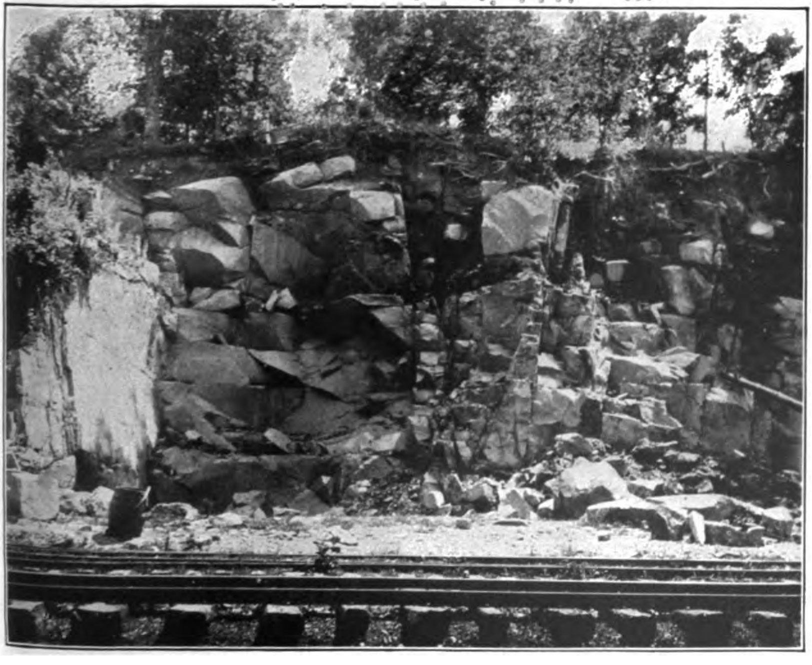
Pressure effects of the usual kind are pronounced in the thin sections of the light-gray granite, and are only slightly discernible in the thin sections of the dark blue-gray type. They are more marked in the granite from the Petersburg part of the area than in that from the Richmond area proper.

Some of the large blocks of the light-gray granite, quarried at the Netherwood quarry during the summer of 1905, showed a fairly well developed schistose structure. Ordinarily the rock belonging to this type from this quarry and from the Richmond area in general appears



A.

STANFORD LIBRARY



B.

JOINTING IN NETHERWOOD QUARRY, NEAR RICHMOND, VA.

A. In gray granite. *B.* In blue-gray granite, which intrudes the gray. Photographs by H. Ries.

massive. In the Petersburg area the pressure effects in the granite of the same type are most pronounced in the thin sections and a tendency toward parallel arrangement of the minerals is indicated in an incipient schistose structure.

DESCRIPTIONS OF QUARRIES.

The Richmond area includes about twenty-five quarries. Of this number less than ten were being operated during 1905 and 1906. These were the McCloy, McGowan, McIntosh, Middendorf, Netherwood, Richmond Granite Company, Winston & Co., and Wray. Some of the others have not been worked for many years, and in part they include the most extensive openings in the area. This is particularly true of the Westham and the Old Dominion Granite Company's quarries.

CHESTERFIELD COUNTY (SOUTH OF JAMES RIVER).

The *Netherwood quarry* is opened in the high granite bluff on the south side of James River about 2½ miles southwest of Richmond. It is one of the largest quarries in the Richmond area, and is reported to have been worked as early as 1845.

Two types or grades of granite, the structural relations of which are shown in figures 4, 5, and 7, are quarried, both of which are biotite granites. One is a medium-textured, light-gray rock; the other a fine-textured dark blue-gray rock. They are essentially similar in mineral composition. The principal minerals are feldspar (orthoclase, microcline, and plagioclase, in variable amounts), quartz, biotite, and a little muscovite. Chlorite, epidote, kaolin, and a light-colored mica are secondary minerals derived from the alteration of the biotite and feldspars. The feldspars all show intergrowths with quartz. Accessory titanite, apatite, and zircon occur. An occasional garnet was noted in all the sections of the fine-textured, dark blue-gray granite. Pyrite is rare; it occurs sparingly along the joint surfaces and occasionally in the granite, but nowhere in a harmful amount.

The quarry has a working face of about 65 feet. Though located only a short distance from James River, its greatest depth is considerably above the stream level and the drainage is good. The stripping consists of about 2 feet of red clay.

The sheets are from 2 to 6 feet thick. Vertical joints strike N. 45° to 65° E. and N. 15° to 75° W. (See Pl. X, *A*, *B*.) The surfaces of some of the joints show slickensides and are coated to some degree in places with pyrite, which shows the movement in the striated and flattened masses of the mineral. Coarse pegmatite dikes up to 12 inches and more in width cut the granite irregularly. Dimension stone is readily obtained and little or no waste is occasioned by the pegmatites.

The granite has an extensive market in and out of the State and is used for general constructional and monumental purposes, curbing, blocks for paving, and crushed stone in all uses made of it. Its principal use is for building and city street work, for which the light-gray type is mostly used. The dark blue-gray, fine-textured granite takes a fine polish and it is a desirable stone for monumental stock.

The *Wray quarry*, opened in the high granite bluffs on the south side of James River, is located about 3 miles southwest of Richmond and about half a mile west of the Netherwood quarry. It has been operated since 1895 for monumental stock exclusively.

The rock is a biotite granite of medium dark color and fine, even grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite. The rock contains accessory apatite and titanite, and secondary chlorite and a light-colored mica. Intergrowths of the quartz with the feldspars and of the feldspars with one another are noted. Twinning structure in the feldspars is marked.

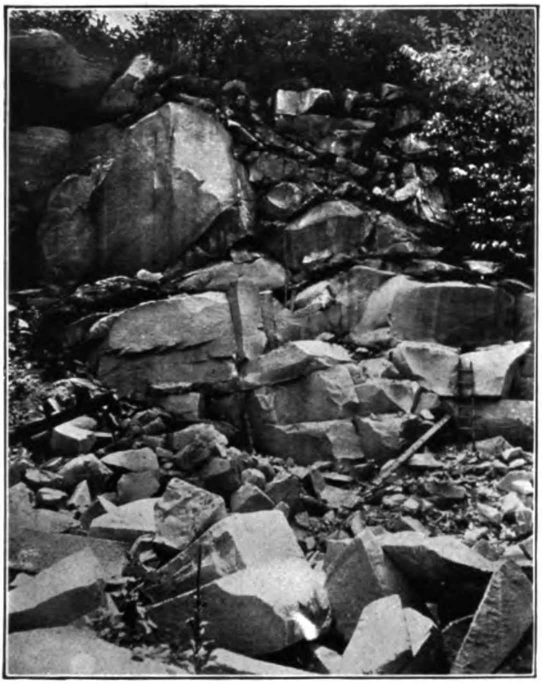
The joints strike east-west and north-south and are so spaced as to admit of dimension stone being quarried. (See Pl. XI, *A*.) Slickensides are developed along the surfaces of the joints, indicating some movement along these directions. Several pegmatite veins or dikes up to 3 inches wide occur.

This granite is practically limited in sale to the principal cities in the State for monument stock.

The *Donald quarry* is located similarly to the Netherwood and Wray quarries, on the south side of James River about 500 yards east of the Belt Line railroad bridge. It is a short distance west of the Wray quarry and farther up the river.

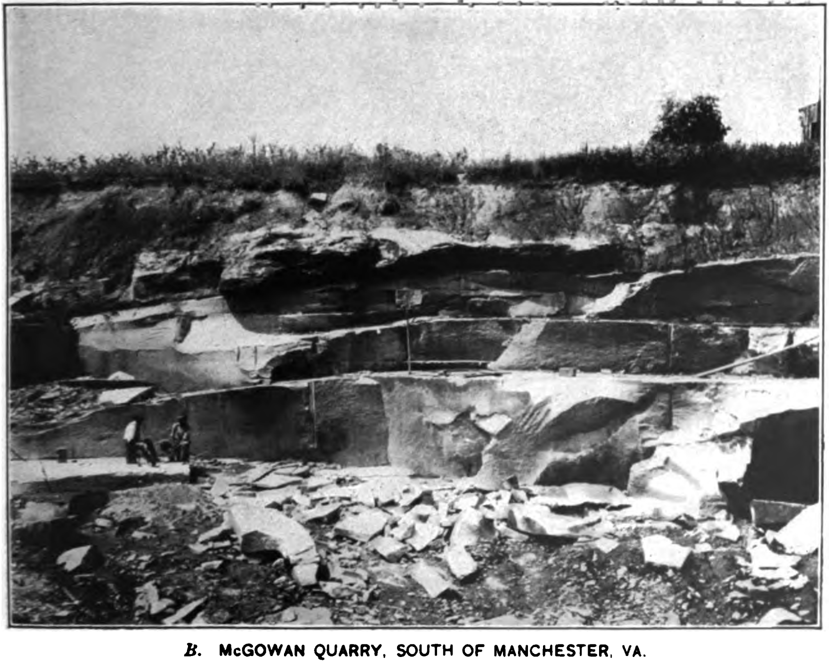
The rock is a biotite granite of fine, even grain and in large part of dark blue-gray color. A zone 6½ feet wide of very light gray granite, containing little or no biotite, of the same fine, even-grained texture as the dark blue-gray rock is exposed near the west half of the quarry. The contacts made by the two granites are entirely sharp and distinct. The minerals of the dark blue-gray granite are potash and soda-lime feldspars (orthoclase, microcline, and oligoclase in variable proportion), quartz, and biotite, with rarely a scale of muscovite. The feldspars are twinned and are intergrown partly with one another and partly with quartz. Accessory apatite and titanite occur and some secondary chlorite and light-colored mica are developed in some of the thin sections. The zone of light-gray granite differs from the dark blue-gray only in the amount of biotite present.

The granite is traversed by joints which strike north-south, east-west, N. 50° to 60° E., and N. 55° W. Slickensides developed along many of the joint surfaces indicate some subsequent movement along



A. WRAY QUARRY, WEST OF RICHMOND, VA.

Showing joint systems. Photograph by H. Ries.



B. McGOWAN QUARRY, SOUTH OF MANCHESTER, VA.

Showing sheeting. Photograph by H. Ries.

these directions in the granite. Pegmatite dikes, ranging in thickness up to 12 inches and more, are somewhat numerous in parts of the quarry and traverse the granite in nearly all directions (Pl. IX, *B*). In several places intersecting of the dikes has resulted in slight displacement (faulting) of the intersected by the intersecting dike, as shown in figure 8.

The quarry has not been worked for several years.

The *McGranigan quarry* is about three-eighths of a mile east of Granite, a station on the Southern Railway, and about one-eighth of a mile west of the Belt Line railroad bridge. The quarry comprises the stripping of an irregular sloping granite surface to a maximum depth of 20 feet, extending back from the water's edge of James River.

The rock is a biotite granite of medium-gray color and medium, even grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory apatite and zircon. The feldspars are partly altered to a little kaolin and a light-colored mica. Chlorite and epidote are noted to some extent as secondary minerals.

Joints strike N. 25° E. and N. 65° W. Several pegmatite dikes of small dimensions intersect the granite. There are a few knots of small size. This quarry has not been worked for some years.

The *Granite Development Company's quarries* comprise a number of small openings several hundred yards west of the McGranigan quarry and about one-fourth mile east of Granite station. The rock is a biotite granite of the same color and texture as that of the McGranigan quarry. Its mineral composition is the same, with perhaps soda-lime feldspar in larger amount. The principal vertical joints strike north-south and N. 65° E.

The *Hawkins quarry*, reported to have been one of the first quarries opened in the Richmond area, is located between James River and the Southern Railway, a few paces east of Granite station. The rock is a biotite granite of medium, even grain resembling that of the Granite Development Company's quarries. Quarrying was confined to the stripping of a gently sloping granite surface to only a shallow depth. It is said that much of the stone was used in the form of riprap for river work about Williamsburg, Portsmouth, Norfolk, and other towns in eastern Virginia. This quarry has been idle for many years.

The *Old Dominion Granite (Middendorf) quarries* comprise two large openings very close together, located several hundred yards south of west from Granite station. The openings are extensive, affording every evidence that large quantities of stone have been quarried from them, but they have not been worked for some years, and at the time of examination in 1906 they were nearly filled with water.

The rock is a biotite granite of medium-gray shade and medium, even grain. Vertical joints strike N. 60° E. and N. 5° W. Pegmatite dikes traverse the granite in places, but they are not numerous enough to cause waste in quarrying. Small, irregular knots are developed to a minor degree.

The *Krimm quarry* is located several hundred yards southwest of the Old Dominion Granite (Middendorf) quarries. The quarry has not been worked for some years, and it was nearly filled with water at the time of examination in 1906. A mantle of light-gray decayed granite and soil, 8 to 12 feet thick, must be stripped before the fresh granite is reached.

The rock is a biotite granite of similar color and texture to that of the Old Dominion Granite (Middendorf) quarries. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with scattered muscovite shreds, and secondary chlorite, epidote, and light-colored mica.

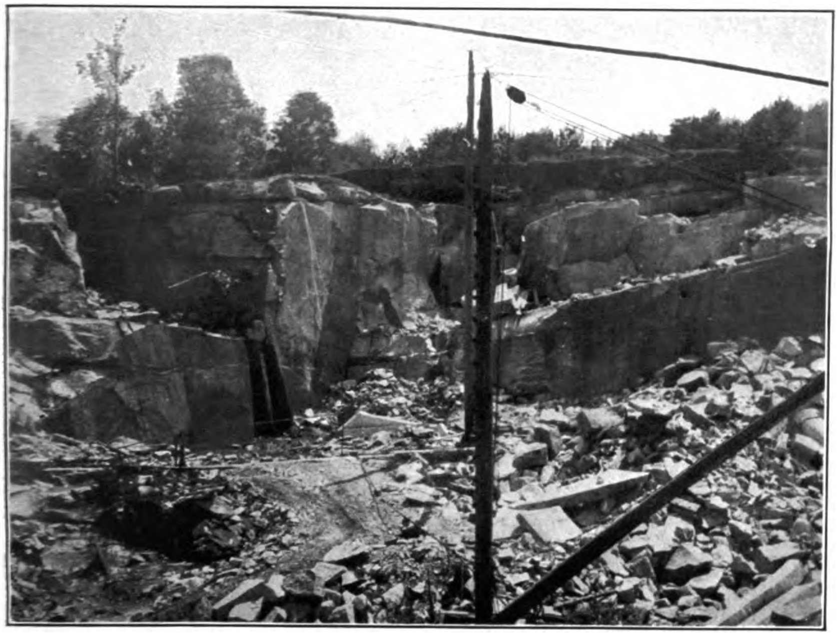
The joints strike N. 55° to 65° E. and N. 15° W., the latter set being somewhat more closely spaced than the former. Very few pegmatite dikes were noted.

The *McIntosh quarry,* formerly known as "flat rock," has been operated for about twenty years and is one of the most extensive working quarries in the State. It is located about three-eighths of a mile southwest of Granite, a station on the Southern Railway 5 miles west of Richmond.

Two types of granite are represented. The principal and dominant type is a biotite granite of medium-gray color and medium-coarse grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and ilmenite and secondary chlorite, epidote, and colorless mica. An occasional grain of pyrite occurs. Orthoclase is intergrown with plagioclase as microperthite. Intergrowths of feldspar and quartz as micropegmatite, feldspar twinning on the Carlsbad law, and micropoikilitic structure in some of the larger feldspar individuals are common. The second type of granite is a biotite granite of dark blue-gray color and fine-grained texture. In mineral composition it conforms entirely with the dominant, medium-gray granite just described.

The quarry opening measures about 250 feet long by 125 feet wide and 45 feet deep. Stripping, where necessary, varies up to 8 feet in thickness.

The sheets are curved and range from a few inches to 5 feet in thickness. There is some "toeing in," owing to the overlapping of lenses. Vertical joints strike N. 85° E., N. 10° W., N. 60° to 65° W., and north-south, and are spaced at intervals of a fraction of an inch up to 6 feet and more. Many of the joint faces are slickensided and



A. MCGOWAN QUARRY, SOUTH OF MANCHESTER, VA.

Photograph by H. Ries.

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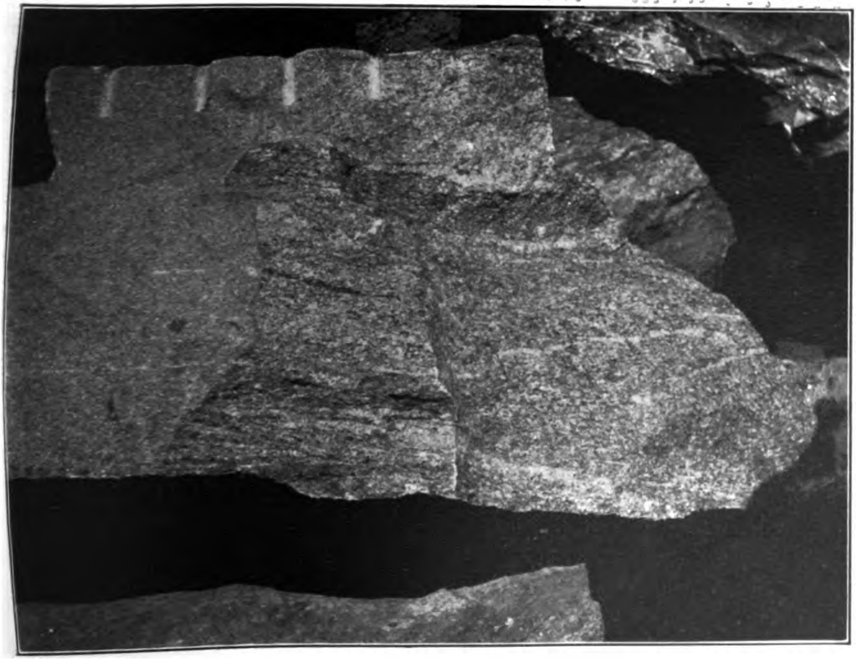

B. GNEISS INCLUSION IN GRANITE AT McGOWAN QUARRY, NEAR MANCHESTER, VA.

Photograph by H. Ries.

are coated with a reddish mineral substance. At the south end of the quarry the granite shows pronounced schistose structure and close jointing.

The product is used principally for street purposes in the form of curbing and blocks, for general building purposes, and for crushed stone, mainly in concreting. It has had a moderate use in monuments.

The *Westham quarries*, comprising a large number of openings along the south side of James River in Chesterfield County, are about 4 miles a little north of west from the city hall in Richmond. The openings are made in the escarpment extending for a distance of about a mile along the river front. Several more recent openings have been worked a short distance from the river to the south and southwest of the old quarries.

The rock is a biotite granite of medium-gray color and medium, inclining to coarse, even grain. The minerals are potash feldspar (orthoclase, with variable but usually much microcline), soda-lime feldspar (oligoclase) in considerable quantity, quartz, and black mica (biotite), with a few intergrown shreds of white mica (muscovite) and accessory titanite, magnetite, zircon, and apatite. The feldspar shows some alteration to kaolin and a colorless mica, and the biotite is partly altered to chlorite. Epidote occurs as an alteration product. The feldspars show some intergrowths with quartz, are twinned on the Carlsbad and albite laws, and contain rounded inclosures of quartz and feldspar.

These are among the largest if not the largest quarries in the Richmond area and supplied the stone from which the State, War, and Navy building in Washington, D. C., was constructed. The largest openings average about 800 by 200 feet by 180 feet deep. The depth of the quarries is considerably below the river level. Quarrying was suspended about 1897. When active, 500 to 800 men were employed and the granite was marketed extensively outside of the State.

In the larger openings the vertical joints strike N. 60° to 65° E. and N. 15° to 60° W. The size of stone quarried was limited to the capacity for handling the stone. Dark-gray knots are noted to a slight extent in places.

The *McGowan quarry* is located in Chesterfield County about 2 miles south of Manchester and about 300 yards east of the Petersburg turnpike. (See Pl. XII, *A*.) It has been worked continuously for about thirteen years and the stone is used exclusively for monumental stock. The quarry waste is worked into blocks for paving.

The rock is a biotite granite of dark blue-gray color and fine, even grain. Its minerals are potash feldspar (orthoclase with some microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), a few shreds of white mica (muscovite), together with accessory apatite, zircon, and titanite. Filaments of rutile are abundant in the quartz. Secondary minerals are chlorite, epidote, and a colorless mica. The feldspars are intergrown with each other and with quartz, and they are twinned on both the Carlsbad and the albite laws.

The sheets, from 4 to 6 feet thick, are thinnest at the top. (See Pl. XI, *B*.) Vertical joints are not so conspicuously developed and are spaced at wide intervals, striking N. 80° E. and N. 30° W. Pegmatite dikes, ranging in thickness up to 5 feet, cut the granite indiscriminately. The principal feldspar in these dikes is orthoclase, containing rounded inclosures of other feldspars and quartz. Black mica (biotite) is sparingly present. A single aplite-pegmatite dike was noted, the relations of which are shown in figure 6. A thin section of the aplite showed predominant plagioclase (oligoclase), the potash feldspars (orthoclase and microcline), and quartz, with an occasional reddish garnet. Some large blocks, measuring several feet across, of a banded granite gneiss were inclosed in the granite (fig. 3; Pl. XII, *B*). A thin section of the gneiss revealed orthoclase and plagioclase (oligoclase) in about equal amount, quartz, biotite, and hornblende, with accessory apatite and titanite and secondary chlorite.

An average depth of about 5 feet of stripping of soil and granite decay is necessary. The granite takes a fine polish, and it has an extensive sale as monumental stock in many States.

The *Middendorf quarry* is located west of Manchester, on the Belt Line Railway, about 760 feet north of the Petersburg turnpike. Several acres of ground has been stripped to a depth of about 25 feet.

The rock is a banded biotite granite gneiss of gray color and medium to coarse, even grain. Its minerals comprise about equal amounts of potash feldspar (orthoclase) and soda-lime feldspar (oligoclase), quartz, and biotite, with some microcline, occasional muscovite, and the usual accessories.

The joints strike N. 65° E. and N. 45° W. and have slickensided surfaces indicating subsequent movement in the granite mass. Pegmatite dikes up to several feet thick are numerous; in direction they may coincide with or cut across (fig. 9) the banding of the gneiss and in dip may vary from nearly vertical to nearly horizontal. The average strike of the gneiss banding (schistosity) is N. 65° E.

The product is used locally for ballast and paving blocks, largely the former.

The *Tidewater Quarry Company's quarry* is located 2 miles southeast of Manchester, immediately on the west side of James River and about 500 yards from the Seaboard Air Line Railway. The quarry was opened prior to the civil war and was last worked in 1905. The stone was shipped by water, being loaded by derricks directly from the quarry into the boats.

The rock is a biotite granite of medium-gray color and medium-fine, even grain. The minerals are potash feldspar (orthoclase and microcline in about equal amounts), soda-lime feldspar (oligoclase), quartz, biotite, and scattered muscovite scales, together with accessory apatite, zircon, and rutile and secondary chlorite and epidote. The feldspars are considerably altered. The orthoclase is intergrown, in part, with a plagioclase.

The principal direction of vertical jointing is N. 10° W. Several zones of very close jointing occur, but in other parts of the quarry the joints are spaced at intervals sufficiently wide to permit the quarrying of dimension stone. Pegmatite dikes of varying thicknesses traverse the granite.

Stripping of 5 to 12 feet is necessary. The quarry has been worked to a depth of 30 to 40 feet. During its last period of working the stone was shipped to Norfolk, Hampton, Old Point, and Newport News, in the form of crushed rock for roads and for use in foundations and granolithic work. A No. 7½ Gates crusher was operated at the quarry for crushing and sizing the stone.

The *Old Dominion Granite Company's quarry*, formerly known as the State quarry and now owned by Mr. Middendorf, is located about 300 yards N. 30° E. of Granite station and about 100 yards north of the Southern Railway. The quarry comprises two large openings within 100 paces of each other and a smaller one lower down on James River. The largest opening is 600 by 225 feet by 100 feet deep. The larger openings were worked for some time by the State, hence the name State quarry. Neither of the openings has been worked for some years.

The rock is a biotite granite of medium-gray color and of medium-coarse, even grain. The minerals are potash feldspar (orthoclase with much microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with a little muscovite, accessory apatite, zircon, magnetite, and titanite, and secondary chlorite, kaolin, and epidote. The feldspars are partly clouded from alteration. Much microperthite is present.

Several thin sections of the altered granite (sap) were examined. The principal changes were opacity of the feldspars from kaolinization; the liberation of much yellow hydrated ferric oxide as a stain from the iron-bearing minerals, biotite and iron ores; and more or less spacing along the cleavages of the feldspars and the sutures of the individual minerals, the first stage in crumbling or granulation.

The granite in the large openings is parted horizontally into sheets of varying thickness near the top, which pass below into massive granite. Vertical joints strike N. 55° E. and north-south. Pegmatite dikes up to several inches in thickness and a few small knots occur.

A large mass of banded gneiss was observed on the lower side of the large opening. Whether this is an inclusion in the granite or an exposure of the country rock (gneiss) in contact with the granite it was impossible to determine, because of failure to reach it for examination. A stripping of 3 to 8 feet of decayed granite and soil is necessary.

Old Dominion Iron and Nail Works quarry, comprising two openings near together which were opened in April, 1902, is located on Belle Island between the cities of Richmond and Manchester.

Two types of granite are represented. The principal one is a biotite granite of medium light-gray color and irregular medium-coarse grain. The second is a biotite granite of dark blue-gray color and fine grain. The principal minerals in both types are potash and soda-lime feldspars, quartz, and biotite.

The larger opening is 480 feet long by 100 feet wide and 65 feet deep. The depth of stripping at the center is 15 feet, with a 50-foot face of granite below. The second opening, made in dark blue-gray granite, is a small one and was not being worked at the time of the writer's visit in October, 1908.

In the large opening vertical joints are widely spaced, and their faces are slickensided. Very few pegmatite dikes occur, and most are of small width. Basic segregations (knots) up to 6 and 8 feet in length are present. The coarse-textured light-gray granite is irregularly banded in places, a feature especially noticeable near the contact with the fine-grained dark blue-gray granite which penetrates it along the contact in well-defined dikes or apophyses, and is accordingly the younger. A uniformly fine-grained light reddish-gray aplite dike, 2 inches thick and having a nearly horizontal position, is observed in an apophysis of the dark-gray granite near the contact with the coarse gray granite.

Vertical joints in the fine-textured dark blue-gray granite of the small opening strike N. 50° to 60° E. and N. 30° W., and are spaced at intervals varying from less than 1 foot up to 6 feet. Pegmatite dikes occur, ranging from 1 to 8 inches in thickness, usually averaging 1 to 2 inches. The feldspar of the small dikes is white; that of the 8-inch dike is of a pronounced red color. Biotite is the mica associated with the feldspar and quartz in these dikes. Knots were not observed in the granite of this opening.

The product is used almost entirely in the form of crushed stone for concrete and ballast. A little of it has been used for road making and for paving blocks. Two crushers, a No. 6 Gates and a No. 4 McCulloch, are operated at the quarry. The stone is quarried by blasting.

HENRICO COUNTY (NORTH OF JAMES RIVER).

The *Richmond Granite Quarrying Company's quarry* is located 4½ miles north of Richmond and about 250 yards east of the Richmond, Fredericksburg and Potomac Railroad. A spur track is operated between the quarry and the main line of the railway. The quarry, opened about eighteen years ago in a bowldery exposure of the granite, measures 500 by 100 feet by 50 feet deep.

The rock is a biotite granite of medium-gray color, and medium, even grain, consisting of potash feldspar (orthoclase and microcline in approximately equal amount), soda-lime feldspar (oligoclase) quartz, and black mica (biotite), together with accessory apatite, zircon, and titanite, and secondary chlorite and kaolin. Plagioclase nearly equals in amount the potash feldspars. A thin section of the decayed granite (sap) shows the feldspars partly altered to kaolin and much stained from the liberation of yellow hydrous iron oxide derived from the alteration of the iron-bearing minerals. Much of the biotite is altered to chlorite.

The granite is not sheeted, but is massive for the entire depth of the quarry. Vertical joints strike N. 30° to 35° E., N. 10° to 70° W., and east-west. The dip varies from vertical to 35° SE. The joints are spaced from 2 to 8 feet or more apart. The joint surfaces usually display well-developed slickensides. Pegmatite dikes up to 8 inches in thickness and of irregular outline (fig. 10) traverse the granite, but are not very numerous.

A second opening, about 400 yards east of the main quarry, in a similar exposure of the granite, was begun late in the summer of 1905.

The stone is shipped to various points in Virginia, Maryland, and Pennsylvania, and to Washington, D. C. It is used for building and monuments and for street work in the form of blocks and curbing. The waste is crushed and sized at the quarry for crushed stone.

The *Smith quarry*, opened in the bluff facing James River, is located at the 5-mile locks west of Richmond, within a few feet of the canal. It was worked many years ago and was last operated in 1903 for riprap used in the river.

The rock is a biotite granite of gray color and medium-coarse, even grain. The minerals are potash feldspar (orthoclase with much microcline), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with accessory apatite, iron ore, and zircon and secondary chlorite, epidote, kaolin, and a colorless mica. Intergrowths of quartz with feldspar and of the feldspars with each other (microperthite) are abundant. The feldspars contain rounded inclosures of quartz and other feldspars.

The quarry has a working face of 40 to 50 feet. The sheets vary from 4 to 10 feet in thickness. Vertical joints strike N. 30° E. and N. 5° to 30° W. Slickensides are developed along the joint-plane surfaces. In parts of the quarry decay extends to the entire depth of the opening. The product shows little or no evidence of oxidation, but is mostly a light-gray granitic sand formed chiefly by physical decay—granulation.

Winston & Co.'s quarry, formerly known as the Mitchell & Copeland quarry, is located at the settling basin, about three-quarters of a mile east of the Smith quarry. Mitchell & Copeland first opened the quarry many years ago and operated it for a period of twelve years. Winston & Co. began working the quarry about 1900 to supply crushed stone and riprap for the construction of the settling basin. The quarry is opened in the bluff facing James River on the north side, and measures 200 by 200 feet by 75 to 100 feet deep.

The rock is a biotite granite of light to medium gray color and medium-coarse even grain. The minerals are potash feldspar (orthoclase with much microcline), soda-lime feldspar (oligoclase), quartz and black mica (biotite), together with accessory apatite, titanite, magnetite, zircon, and muscovite. Secondary chlorite and epidote occur, the latter sparingly.

The granite is separated into horizontal sheets, which are thick and massive at the bottom of the quarry and thinner near the top. Vertical joints strike N. 30° to 70° E., N. 5° W., and eastwest. Pegmatite dikes up to several feet in thickness intersect the granite, but are not numerous.

The stone obtained for building the settling basin was quarried by blasting with powder and dynamite. It was conveyed by tram cars and overhead cranes from the quarry to the crusher near by.

The *Philadelphia quarries*, comprising three large openings close together, are located at the extreme east end of the settling basin, less than a mile south of east from Winston & Co.'s quarry, about 100 yards north of James River, on the north side of the Chesapeake and Ohio Railway. The quarries were last worked about seventeen years ago, and at the time of the writer's examination the openings were so nearly filled with water that not much information could be obtained from a study of them.

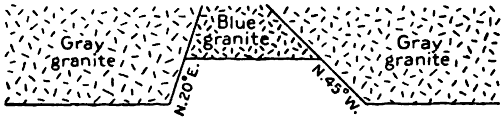

FIGURE 13.—Section at Philadelphia quarries, near Richmond, Va., showing relations between the blue and gray granites.

Two grades of granite were quarried—one of medium-gray color and medium-coarse grain, the other of dark blue-gray color and fine grain. The relations of these two granites are shown in figure 13. The fine-grained dark-gray granite is intruded into the coarser, lighter-gray granite. Mineralogically the two granites are essentially alike; they are biotite granites.

The fine, even-textured granite contains potash feldspar (orthoclase and microcline in nearly equal amount), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with accessory apatite, magnetite, and occasional scales of muscovite. The medium-gray and medium, even-textured granite contains potash feldspar (orthoclase with much microcline), variable soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with accessory apatite, zircon, and magnetite. The secondary minerals are chlorite, kaolin, and a light-colored mica. The feldspars exhibit the usual twinning and are intergrown with one another and with quartz.

The openings are reported to have been worked to a depth of 90 feet. Vertical joints strike N. 20° to 70° E. and N. 20° to 45° W. Slickensides are developed along the joint surfaces and the jointing is sufficiently spaced to allow the quarrying of dimension stone. The granite is intersected by pegmatite dikes, but these are not numerous.

The city hall in Richmond was built in part from the granite of these quarries. Much of the product was shipped to Washington, D. C., and to Philadelphia for use as a building and street stone.

The *McCloy quarry*, opened in a flat-doming surface exposure of granite, is located about 300 yards from the James River branch of the Richmond, Fredericksburg and Potomac Railroad, and about a quarter of a mile west of the new reservoir. The quarry opening covers nearly an acre of ground, worked to an average depth of less than 18 feet.

The rock is a biotite granite of medium dark-gray color and fine, even grain. Its minerals are potash feldspar (orthoclase with much microcline), soda-lime feldspar (oligoclase), quartz, and black mica (biotite) intergrown with occasional shreds of white mica (muscovite), together with accessory apatite, zircon, and magnetite. Secondary chlorite and a light mica occur. The orthoclase is intergrown in part with a plagioclase.

The granite is massive and is not sheeted horizontally. The vertical joints strike N. 10° to 75° E. and N. 5° to 85° W. and dip from vertical to 55° NW. A minor set of joints strikes north-south. Slickensides are developed along the joint planes. Very few pegmatite dikes were observed, and these measured less than an inch in thickness.

The granite is decayed in places to a depth of 3 or 4 feet, and this material must be removed before the fresh stone can be obtained. The principal uses made of the product are for monuments and building and for street work as blocks and curbing. The quarry waste is crushed and utilized for street concrete or cement work. The product is marketed in a number of States. The quarry has been worked for about eight years.

FREDERICKSBURG AREA.

INTRODUCTORY STATEMENT.

The Fredericksburg area includes the region west and north of the city of Fredericksburg in Spottsylvania and Stafford counties. The granite exposed along Rappahannock River northwest of Fredericksburg extends across the river for some distance into Stafford County, but no quarries have yet been opened in that county.

Two types of granite have been quarried in the Fredericksburg area—one a very light gray, medium-textured muscovite granite, the other a dark blue-gray, very fine textured biotite granite. The latter is identical in texture and composition with the fine-grained dark blue-gray granite quarried in the Richmond area and extensively used for monument stock. The granite in the Fredericksburg area is a shade darker in color than the granite in the Richmond area; it is an excellent monumental stone and has wide use for that purpose. The dark blue-gray granite of the Richmond and Fredericksburg areas has been described elsewhere.[a]

DESCRIPTIONS OF QUARRIES.

Hazel Run quarry.—A light-gray muscovite granite of medium texture is exposed along Hazel Run, a tributary of Rappahannock River, about a mile west of Fredericksburg. It resembles somewhat the light-gray muscovite granite of Stone Mountain, 16 miles east of Atlanta, Ga., which has been and is used so extensively for general building purposes. In the spring of 1879 an opening was made in the exposure immediately on the south side of Hazel Run, about a mile west of Fredericksburg, and enough stone was quarried to build the Presbyterian Memorial Chapel in Fredericksburg. None of the stone has been quarried since. The joint planes are widely spaced; the best-developed ones strike N. 75° W. and north-south.

Thin sections of the granite show potash feldspars (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, the white and black micas (muscovite and biotite), apatite, rutile, and zircon. The principal secondary minerals are chlorite and muscovite, the former derived from the alteration of the biotite. Muscovite is partly primary and partly secondary. Biotite is very subordinate in amount. Microcline and plagioclase are abundant. Intergrowths of the feldspars and of the feldspars with quartz are numerous. Partial orientation of the mica along parallel directions, an occasional bent and broken muscovite shred, fractured quartz with wavy extinction, and the perfect granulation of the quartz-feldspar individuals are pressure effects plainly marked in the thin sections.

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[a] Watson, T. L., Lithological characters of the Virginia granites: Bull. Geol. Soc. America, vol. 17, 1906, p. 528.

On close examination a thinly foliated structure is discernible in hand specimens of the rock and an occasional red garnet may be seen.

Cartwright & Davis quarries.—About 3 miles northwest of Fredericksburg the granite is exposed along the Rappahannock in steep bluffs and low bowlder ledges, which offer good quarry sites. On the Spottsylvania County (south) side of the river the Cartwright & Davis quarries are opened in the granite bluffs immediately along the river. Numerous openings have been worked, extending along the river front for half a mile or more.

The rock is a biotite granite of dark blue-gray color and fine-grained texture. In color it is a shade darker than the rock of the same type in the Richmond area. It consists of potash feldspar (orthoclase and some microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and accessory muscovite, apatite, rutile, and zircon. The feldspar is partly intergrown with quartz in granophyric structure, indicating overlapping of the periods of formation of the two minerals. Orthoclase and plagioclase are present in nearly equal amounts, but microcline is very scant. The quartz contains abundant threadlike inclusions of rutile, and the biotite is largely altered to chlorite.

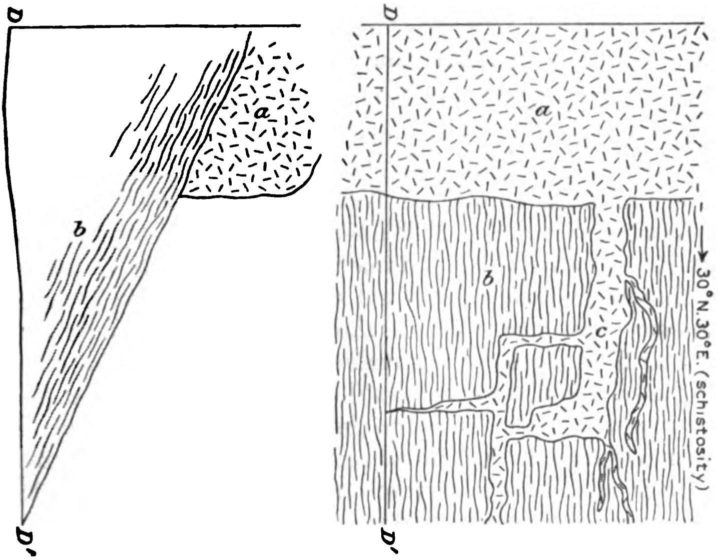

FIGURE 14.—Sketch in Cartwright & Davis quarry, near Fredericksburg, Va., showing relation of granite to gneiss.

The granite is intruded into an irregular hornblende-biotite gneiss (fig. 14) The general strike of the schistosity of the gneiss is N. 25°. to 40° E. The granite is cut by several sets of joints so spaced as to admit of the stone being quarried in blocks of any size. The strike of the principal joint planes in the quarry openings is north-south, dipping 40° E.; N. 60° to 80° E., dipping 10° to 30°; and N. 20° to 80° W. Pegmatites are abundantly developed in places and occasion considerable waste in quarrying.

The granite is quarried exclusively for the monument trade. The monuments have an extensive market both in and out of the State. The granite takes a fine polish, the durability of which is favored by the uniformly small size of the biotite scales. No dimension stone is sold in the rough, but it is all worked up at the yards near the northern limits of Fredericksburg, where the equipment is ample for all grades of polished and dressed work. The stone is conveyed from the quarries to the yards by canal. A crusher is operated at the yards for sizing the waste, which is utilized for local purposes.

FAIRFAX COUNTY AREA.

INTRODUCTORY STATEMENT.

A complex of igneous rocks, largely altered, comprising chiefly granite, granite gneiss, gabbro, and diorite, mapped by Williams and Keith as Archean,[a] extends southwestward from Maryland and the District of Columbia across the Potomac into Fairfax County, Va., passing immediately west of Washington. This rock complex has been extensively altered by metamorphism and much of the original massive material has been rendered schistose. Massive granites and basic igneous rocks occur within the area, but they are subordinate in extent to their schistose equivalents. Because of the structure, rocks of the schistose class are less desirable for commercial purposes than the massive types. Granite gneiss is the most abundant rock type and many portions of it furnish good material for foundations and similar rough work. It is easy to quarry and is strong and durable. In many places it contains pyrite, unfitting it for ornamental use. Rock is also quarried from the less schistose portions of the granite masses at a number of places in the county. It is homogeneous, of even texture and good color and works out readily into stones of moderate size. Some portions of the rock in the Falls Church area are colored by pink feldspar.

DESCRIPTIONS OF QUARRIES.

Granite has been quarried in Fairfax County to a small extent in the vicinity of Falls Church and Annandale, strictly for local use.

FALLS CHURCH AND VICINITY.

The granites in the vicinity of Falls Church are of two varieties. One is a medium to fine grained rock and contains dominant biotite, with some muscovite as a third essential component. The ratio of muscovite to biotite is variable, but muscovite occurs in considerable amount at a few places. The microscope shows that the granite of this type contains principally orthoclase and quartz, some microcline, and a small but variable amount of soda-lime feldspar (oligoclase), with biotite and muscovite and the usual accessory minerals. The biotite is largely altered to chlorite and the muscovite is, in part, at least, secondary. An occasional garnet is noted in some of the thin sections. Pressure effects of the usual kinds are plainly seen on microscopic examination.

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[a] Washington folio (No. 70), Geol. Atlas U. S., U. S. Geol. Survey, 1901.

The second variety of granite occurring near Falls Church, a light and dark colored rock, is more coarsely crystalline than that just described and is a hornblende-biotite granite. It is somewhat closely allied to quartz diorite and is closely associated in the field with diorite masses on the one hand and with foliated mica granite on the other. It more properly belongs with the granodiorites, differing from the diorites proper in increased quartz and potash feldspar.

Thin sections show quartz, plagioclase, orthoclase, green and brown hornblende, biotite, apatite, rutile, and the secondary minerals epidote, sericite, garnet, chlorite, and kaolin. Hornblende is one of the most abundant constitutents, and in places it completely incloses shreds of the biotite. Microcline does not occur. Plagioclase feldspar is probably a little more abundant than orthoclase. Pressure effects are indicated in the optical disturbance of the quartz and feldspar; in fractures crossing the quartz; in curved and bent lamellæ of a part of the plagioclase; and in the marked distortion of the cleavage angle of the hornblende.

The *Trip quarry,* located about a mile south of Falls Church, has supplied considerable stone for local use, principally for foundations and buildings. The rock is a massive granite of medium grain and variable light-gray color, depending on the amount and distribution of the mica present. Several sets of joints are developed which usually cut the granite at close intervals and limit the size of stone that can be quarried. The directions of these joints are N. 10° to 80° E. and N. 10° to 80° W. The Presbyterian and Catholic churches at Falls Church were constructed of the granite in the rough from this quarry.

ANNANDALE AND VICINITY.

The granite quarried several miles west of Annandale is a medium-gray, medium-grained, massive biotite granite, intermediate in color and texture between the Richmond light-gray and dark blue-gray types described on pages 74–76. It is similar in mineral composition to the Richmond types. · Orthoclase is the dominant feldspar. Considerable microcline is present, but plagioclase is less abundant than elsewhere. A sprinkle of idiomorphic sections of garnet is noted.

Crushing effects are discernible under the microscope in the partial granulation of the quartz and feldspar, with the fine mosaic filling the interspaces of the unmashed portions of the two minerals.

The *Hoffman & Miller quarry*, located about 2 miles west of Annandale, is opened at about water level directly on the west side of Accotink Creek. The opening was made in a bowlder ledge exposure. Stripping of 8 to 10 feet of soil and red clay is necessary for the quarrying of fresh granite. The strike of the joint planes is north-south and N. 50° to 80° W.; they are spaced widely enough to permit the quarrying of dimension stone.

BLUE RIDGE REGION.

GENERAL DISCUSSION OF THE GRANITES.

In the northern Blue Ridge of Virginia granite has wide distribution, extending from Maryland across the Potomac southward for some distance southeast of Front Royal. As a rule, the granite areas are distributed in long, narrow belts, which vary in width up to 6 miles. The outcrops of granite increase in number and extent southward from the Potomac in Virginia.

According to Keith,[a] the mineralogical composition of the granite is fairly constant over large areas. Six varieties are distinguished, each having a considerable areal extent. The essential minerals given by Keith are quartz, orthoclase, and plagioclase feldspar. By the addition to these of biotite, garnet, epidote, blue quartz, and hornblende, five types are formed. Texturally the granite ranges from coarse to very fine grained. Keith gives the following microscopic description of the different types:[b]

> Epidote granite, 3 miles west of Aldie, Va., is composed of fine-grained quartz, plagioclase, orthoclase, and biotite both unaltered and altered to chlorite. Accessory minerals are magnetite, a little eipdote, and some doubtful allanite. Another specimen from the same locality shows a coarse holocrystalline mass of quartz, orthoclase, a little plagioclase, and epidote. The epidote is both granular and crystalline and is associated with quartz (rarely feldspar) in groups of crystals. A third specimen from the same locality shows epidote in bunches of crystals and as inclusions in the feldspar.
>
> Garnetiferous granite from the Potomac River 1 mile east of Harpers Ferry shows quartz, orthoclase, plagioclase, garnet, epidote, and apatite; all except the last two are in large crystals. Dynamic action has caused considerable alteration of feldspar to quartz, muscovite, and chlorite, and cracks in the quartz, which are cemented with chlorite. A specimen from the granite 4 miles southwest of Hillsboro, Va., contains quartz, plagioclase, orthoclase, pink garnet, magnetite, and a little chloritized biotite.
>
> Granite from 1 mile northwest of Browntown, Va., shows quartz, orthoclase, plagioclase, hornblende, a little biotite, magnetite, and, along the feldspar cleavage, chlorite. Another specimen from the same locality shows the same minerals in larger crystals. A third specimen contains a large amount of garnet in rude crystals and fragments, a little apatite and pyrite, and but very little orthoclase.

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[a] Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 299; Harpers Ferry folio (No. 10), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

[b] Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 300.

The biotite variety is far the most common. The biotite is always small in amount and often absent, so that the rock has a prevailing light-gray color. Its minerals are quartz, orthoclase, plagioclase, biotite, magnetite, and usually a little secondary muscovite and chlorite from feldspar decomposition.

The varieties of granite characterized by blue quartz do not differ under the microscope from other varieties containing biotite. As a macroscopic constituent, however, the blue quartz is very striking, and the brilliancy of its color renders it noticeable wherever seen. It occurs both as original crystals disseminated through the mass and as veins and patches.

The granite of the Blue Ridge region is usually light gray in color and has been extensively altered by pressure. According to the degree of alteration the rock is granite, gneiss, or quartz schist. No quarries have been opened in the granite, but where bowlders could be obtained without much labor they have been worked up and the granite used locally.

UNAKITE.

The name unakite was applied by Bradley[a] in 1874 to a variety of granite from the Unaka Mountains in North Carolina, composed of the essential minerals yellow-green epidote, pink feldspar, and quartz. Unakite has since been noted at two localities in Virginia—(1) at Milams Gap, near Luray, in Page and Madison counties,[b] in the Blue Ridge of northern Virginia, and (2) about 2½ miles south of Troutdale, Grayson County,[c] in the Blue Ridge region of southwestern Virginia.

The mineral composition of the unakite from the Virginia and North Carolina–Tennessee localities places it among the granites, with epidote as an essential constituent, but, according to an analysis by Phalen, quoted below, of specimens from Milams Gap, Virginia, the rock is relatively basic for a granite.

In the Milams Gap locality the unakite is a moderately coarse but irregular crystallization of red feldspar, quartz, and green epidote. Irregular crystallization of the rock is shown in the variation from masses composed of more than two-thirds of the red feldspar through all gradations to masses composed of quartz and epidote without feldspar—epidosite.[d] Thin sections of the unakite from Milams Gap show epidote, orthoclase, quartz, iron oxide, zircon, and apatite. The epidote is here secondary, as in the other localities, replacing pyroxene and feldspar, both plagioclase and orthoclase. The unakite from Grayson County, Va., shows deeper-colored feldspar and epidote than that from Milams Gap. Analyses of the unakite and the unakite-bearing rock at Milams Gap are given on page 78.

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[a] Bradley, F. H., Am. Jour. Sci., 3d ser., vol. 7, 1874, pp. 319, 320.

[b] Merrill, G. P., Stones for building and decoration, 1903, p. 86. Phalen, W. C., Smithsonian Misc. Coll., vol. 45, 1904, pp. 306–316.

[c] Watson, T. L., Am. Jour. Sci., 4th ser., vol. 22, 1906, p. 248.

[d] Phalen, W. C., op. cit., p. 312.

The strikingly beautiful combination of colors produced by the peculiar green of the epidote and the pink or rose red of the feldspar makes the rock especially desirable for use, when polished, in certain forms of interior ornamental work. Should the rock be found to exist in quantity, the quarrying of it would certainly prove profitable.

AREA IN NOTTOWAY AND PRINCE EDWARD COUNTIES.

In the northwest corner of Nottoway County and in the adjacent portion of Prince Edward County is a promising area of massive gray granite of fine-grained texture and uniform color, which has been opened and quarried for local use at a single point in each county. The granite is exposed at the surface in flat-doming masses and as bowlders. This area lies close to the Southern and the Norfolk and Western railways, which afford ready transportation facilities.

The *Wingo quarry*, in Nottoway County, located between Jennings and Jetersville on the east side of the Southern Railway, was operated on a small scale some years ago for ballast. The rock is a fine-grained, massive, medium-gray biotite granite of uniform color and texture.

In the vicinity of Rice Depot, Prince Edward County, granite was quarried some years ago for use in bridge construction along the Norfolk and Western Railway.

CHARLOTTE COUNTY.

The *State Test Farm quarry* is located on the state farm on the southeast side of the Richmond and Danville division of the Southern Railway, near Saxe station. A very small amount of stone has been quarried here from a bowlder-ledge exposure strictly for local use.

The granite is a hornblende-biotite granite of pronounced red color and medium grain. It has a marked schistose structure imparted by the orientation of hornblende and biotite. Very small miarolitic cavities occur in the granite. The feldspar is entirely of red color, to which is due the pronounced red color of the rock. Hornblende is considerably altered in places, partly to chlorite and epidote and partly to iron oxide.

The stone quarried from this outcrop was used in the construction of bridges over some of the small streams in the neighborhood.

FLUVANNA AND GOOCHLAND COUNTIES.

The *Cowherd quarries* are located on the north side of James River, along the James River division of the Chesapeake and Ohio Railway, partly in Goochland County and partly in Fluvanna County, at Columbia.

The rock is a biotite granite gneiss of medium dark-gray color, fine grain, and fine, regular, straight banding. Its principal minerals are feldspar (potash and soda-lime varieties), quartz, and biotite.

A steep slope paralleling the river and the railroad for a distance of 1,500 feet has been worked by irregular stripping. No work has been done on the Fluvanna County side for more than twenty-five years. On the Goochland County side quarrying operations were suspended about 1900.

The strike of the schistosity (gneissic banding) is N. 45° E. The vertical joints are widely spaced, striking N. 10° E., N. 35° W., and N. 55° W. Quartz veins of irregular bulbous shape, varying from a fraction of an inch up to 2 feet in thickness, are numerous. These are seamed with knife-edge layers of biotite altered to chlorite occupying central and contact positions, which both cut across and conform with the schistosity of the inclosing granite gneiss. That these veins were formed prior to the period of deformation inducing schistosity in the inclosing rock is shown in the fracturing of many of the quartz masses in directions coincident with that of the schistosity, as indicated in figure 15. A few knots up to 6 or 8 feet long occur.

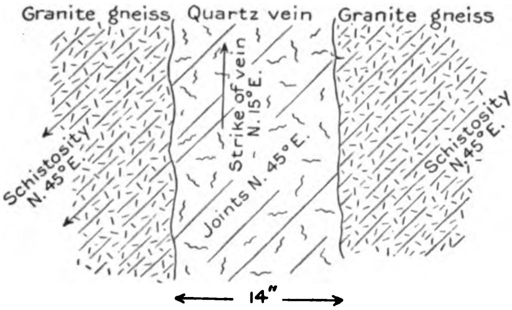


FIGURE 15.—Quartz vein in Cowherd quarries, Columbia, Va., showing jointing coincident with schistosity of inclosing gneiss.

LUNENBURG COUNTY.

The *Kenbridge quarry,* located on the north side of the Virginian Railway, near Kenbridge, in Lunenburg County, was opened about five years ago to supply crushed stone for railroad ballast. The writer has not visited the quarry, but specimens of the rock show it to be a biotite granite gneiss of medium color and texture.

PRINCE WILLIAM COUNTY.

Several granite quarries are opened close together immediately on the northwest side of Occoquan Creek, opposite Occoquan village, in Prince William County (Pl. VII). The rock is a thinly foliated biotite granite of medium gray color and texture. It is used principally in the form of crushed stone for concrete, and locally for building. The rock is crushed and sized at the quarry and shipped to Washington, D. C., for use in concrete.

OTHER GRANITE AREAS.

In addition to the areas described above, many other counties of the Virginia crystalline region contain granite that is suitable for general building and other purposes, but in none of these has it been developed. So far as these undeveloped areas have been examined, the granite conforms to one or the other of the types of the developed areas. They are prevailingly mica granites, containing biotite either with or without muscovite, fine to medium in texture, and usually some shade of gray in color.

CHAPTER IV.

THE GRANITES OF NORTH CAROLINA.

DISTRIBUTION OF THE GRANITE.

Granites are distributed over about one-half the total area of North Carolina, but the productive part of this area is considerably less. Openings from which some granite has been quarried have been made in most of the counties in which granite occurs, but only a few quarries are being systematically worked at present.

Geographically, granites are distributed over parts of each of the three larger physiographic provinces of the State—the Coastal Plain, the Piedmont Plateau, and the Appalachian Mountains. The areas are fewer and smaller in the Coastal Plain region, and more numerous and larger in the Piedmont Plateau region, where granite forms one of the dominant rock types.

For convenience of description the granites and gneisses may be divided into the following belts, the location of which is indicated on the accompanying map (Pl. XIII):

I. The Coastal Plain region.
II. The Piedmont Plateau region.
    (1) The northeastern Carolina granite belt.
    (2) The Carolina metamorphic slate and volcanic belt.
    (3) The Carolina igneous or main granite belt.
    (4) The Western Piedmont gneiss and granite belt.
III. The Appalachian mountain region.

This division of the State into belts is essentially the same as that adopted by the State Geological Survey, and the map is the one compiled from the records of the State Survey to accompany Nitze and Hanna's report on the gold deposits of North Carolina.

SCIENTIFIC DISCUSSION.

KINDS OF GRANITE.

On the basis of texture and structure three types of granite are distinguished—(1) the massive even-granular (normal) granites; (2) the porphyritic granites; and (3) the banded or schistose granites (granite gneiss). Field and laboratory study develops close similarity of mineral composition in the three types. The even-granular and porphyritic textures represent different phases of the same rock mass.

The granite gneisses differ essentially from the massive granites in having a pronounced schistose structure, induced by pressure metamorphism.

On the basis of mineral composition, the granites of North Carolina are divisible into four principal types—(1) biotite granite, which may or may not contain a little muscovite (usually scant muscovite is present), to which most of the granites of the State belong, including those of the Mount Airy, Dunns Mountain, and Greystone areas; (2) hornblende-biotite granite, represented by a part of the granites in the northern and southern parts of Mecklenburg County; (3) muscovite granite, with or without biotite, represented by a small area near Warren Plains, in Warren County; and (4) the epidote granite (unakite) of Madison County, N. C., and Cocke County, Tenn.

MINERAL COMPOSITION.

The granites of North Carolina conform in mineral composition to those of the other States in the southern Appalachian region. There are mixtures of feldspars and quartz, with biotite as the third essential mineral in the most important areas. Muscovite in association with biotite is present in small amount in many of the biotite granites of the State, and it is an important component in the area near Warren Plains, in Warren County. Hornblende is an important constituent in a part of the granites near and east of Davidson, and 5 miles south of Charlotte, in Mecklenburg County. It is sparingly noted in the biotite granite near Elm City (Toisnot), in the extreme northern part of Wilson County. It does not occur in the commercially more important granites of the State. Epidote is a principal constituent of the granite known as unakite, in Madison County. The epidote is entirely secondary.

The feldspathic constituent includes orthoclase, microcline, and acidic plagioclase, either oligoclase or albite or both. In most places the soda-lime feldspar exceeds in amount the potash feldspars, but in others it may be equal or less. As a rule, the North Carolina granites are relatively rich in plagioclase. Microcline is variable in quantity and in places is entirely lacking.

The common accessory minerals include apatite, zircon, titanite, magnetite, ilmenite, and here and there other minerals in very sparing amounts.

CHEMICAL COMPOSITION.

Very few chemical analyses of North Carolina granites have been made. Those available are from widely separated areas, and, though not so complete with respect to all the constituents as the present-day analyses, they serve to indicate two important points—the acidity and the character and ratio of the feldspathic constituents.

Partial analyses of North Carolina granites.

Constituents.	1.	2.	3.	4.
Silica (SiO_2)	75.14	70.70	69.28	66.01
Lime (CaO)	.93	2.96	2.20	1.44
Soda (Na_2O)	5.82	4.56	3.64	5.06
Potash (K_2O)	2.57	2.45	2.76	3.16

1. Pink granite from Pink Granite Company's quarry, Dunns Mountain, Rowan County: First Bienn. Rept. North Carolina Geol. Survey, 1893, p. 89.
2. Light-gray granite from Mount Airy quarry, Surrey County: Idem, p. 94.
3. Gray granite from City quarry, Raleigh, Wake County: Geology of North Carolina, vol. 1, 1875, p. 122.
4. Gray granite from Johnson quarry, near Mooresville, Iredell County: First Bienn. Rept. North Carolina Geol. Survey, 1893, p. 87.

STRUCTURAL FEATURES.

JOINTS.

With possibly one or two exceptions, the North Carolina granites are characterized by a strong development of vertical joints, which break the rocks into polygonal blocks of different sizes. The most noteworthy exception is the extensive granite area near Mount Airy, Surrey County, in which vertical jointing is not visible. Measurements of the vertical joints were made in all the openings and quarries of granite in the State, and the results show four sets—the major joints, whose planes lie in the northeast and northwest quadrants, and two minor sets, whose planes strike east-west and north-south. The major joints vary in strike from N. 10° E. or W. to N. 80° E. or W. Of the total number of vertical joints measured 56 lie in the northeast quadrant, 45 in the northwest quadrant, 19 have a north-south strike, and 16 east-west.

The surfaces of the vertical joints usually show smooth, somewhat polished and striated faces, which indicate some movement in the granite masses since the formation of the joints. Striæ are developed in a thin coating or skin of yellow to yellowish-green mineral, which probably is damourite in most places, but locally, epidote, or a mixture of the two derived from certain original minerals of the granite, and caused probably by the rubbing together of the two sides along the plane.

BASIC SEGREGATIONS (KNOTS).

The distribution of knots in the granite is subject to much variation. From some quarries they are entirely absent, in others they occur only here and there, and in others still they are so abundant as to disfigure the granite and preclude its use in certain higher grades of work. The knots vary in size from a fraction of an inch to more than a foot across. They are of irregular outline, varying from those that are roughly oval or round to those that are greatly elongated.

DIKES.

Genetically. the intersecting materials are of two kinds—true dikes and true veins. These are strongly contrasted in some places, and everywhere they show differences to some degree in both texture and composition.

BASIC IGNEOUS DIKES.

Dikes of basic igneous rocks, chiefly diabase or its altered form, penetrate the granites of most of the important areas in the State. Thinly schistose dikes of amphibolite, composed largely of hornblende with accessory feldspar and quartz, are common in some of the quarries.

The widest dikes exposed in the granite openings do not exceed 50 feet and many are less than 6 feet. Where a number of dikes are exposed the intervals between them vary greatly. Within a zone of 12 to 15 feet two or more dikes may occur, always parallel and coincident with the vertical joints in that direction. More commonly, however, the intervals at which the dikes intersect the granite are considerably greater. The dip of the dikes is vertical or departs only a few degrees from the vertical, a feature likewise characteristic of the joints.

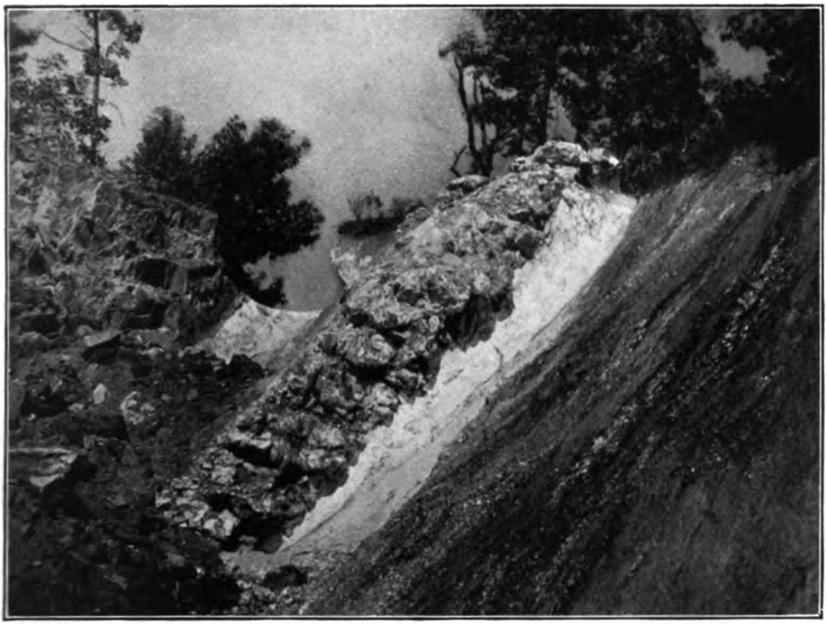
The following table makes clear the relationship between the strike of the dikes and that of the vertical joints:

Strikes of dikes and vertical joints in granites of North Carolina.

Locality.	County.	Strike of dikes.	Strike of joints.
Charlotte City quarry	Mecklenburg	N. 40° E.	N. 40° E., N. 35-50° W.
Greensboro, 1¼ miles north of	Guilford	N. 20° E.	N. 20° E., N. 50° E., N. 20° W.
Jamestown, ½ mile southeast of	do	N. 40° W.	N. 40° W., N. 20° E.
Davidson, ⅓ mile east of	Mecklenburg	N. 15-20° W.	N. 20° W., N. 70° E.
Rolesville, ¾ mile southwest of	Wake	N. 20° E.	N. 20° E., east-west.
Lilesville, ¼ mile north of	Anson	N. 20° W.	N. 20° W., N. 70° E., north-south.

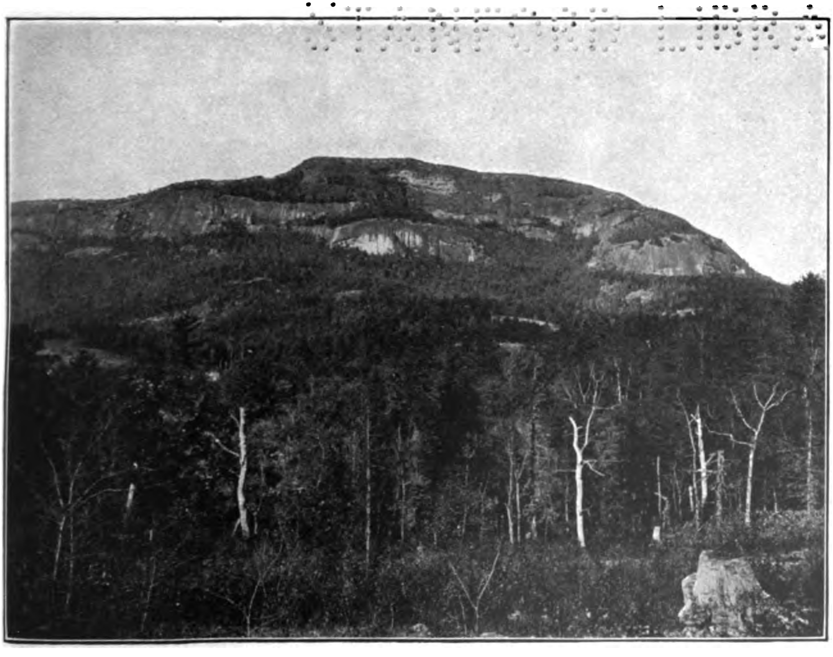
GRANITE DIKES.

True granite dikes of normal composition and usually of fine grain are numerous in certain areas, but only one or two have been observed penetrating the granite masses. In the main granite belt of the Piedmont region dikes of this character, penetrating the surrounding rocks, are common, and are regarded as apophyses from the granite masses. As a rule, they are irregular in outline and fine grained, and are composed of quartz and light to pink feldspar, with mica subordinate, if present at all. They range from a few inches to several feet in thickness.



A. PEGMATITE VEIN WITH QUARTZ CENTER.

Harris clay mine, northeast pit, 2½ miles north of Bryson, N. C.



B. WHITESIDE MOUNTAIN, A GRANITE DOME, JACKSON COUNTY, N. C.

The principal localities where the granite dikes have been noted are northeast of Concord, in Cabarrus County, for several miles along the Concord–China Grove road; near Concord and to the east along the Mount Pleasant road; along the east and west roads leading out of Salisbury, a short distance from the town; 5 miles west of Barber Junction, near Elmwood, Iredell County; in the cuts of the Southern Railway near Lexington, Davidson County; and in the railroad cuts north and south of High Point, Guilford County.

PEGMATITES.

Pegmatite dikes intersect the granite in most of the quarries in the State. They are so abundant in parts of some quarries that dimension stone is difficult to obtain. This is especially true of the granite in the Raleigh City quarries, where hardly a block of granite can be quarried that is entirely free from the quartz-feldspar dikes, a feature strikingly shown in the state capitol in Raleigh, built of this stone. In some quarries pegmatites are but sparingly developed, and in others they are entirely absent.

Where observed they are characterized by the usual coarse texture, and are composed principally of feldspar and quartz with subordinate stout platy black biotite (Pl. XIV, *A*). The feldspars are partly pink and partly white in color, are highly lustrous, with a good cleavage development, and are commonly twinned on the Carlsbad law.[a] Feldspar is the most abundant constituent, the quartz locally diminishing to a very subordinate amount. Biotite is usually present in large, stout platy forms, in some places irregularly distributed between the feldspar and quartz, in others distributed along a central axis in the vein or dike. Muscovite has been observed in the pegmatite bodies only occasionally, and tourmaline, garnet, and the rarer minerals associated with some pegmatite dikes are strikingly absent.

Some of the pegmatites are very extensive, though usually narrow, apparently deep seated, and of aqueo-igneous origin. Others are of minor extent and are surrounded entirely by the granite, being probably true veins of segregation. In the Raleigh City quarry, where the only true aplite dikes have been observed, the aplite and pegmatite are associated as banded aplite-pegmatite. As a class the pegmatites are irregular in outline, conforming to no definite or fixed direction, but cutting the granite at random and at all angles.

In the Raleigh City quarry, the Carrigan quarry, 3 miles northeast of Mooresville, Iredell County, and the Walker quarry, 1½ miles southeast of Ridge Summit station, Guilford County, many of the pegmatites intersect one another, producing a faulted condition of several inches displacement.

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[a] See analyses of feldspars, p. 170.

APLITES.

Aplite dikes have been observed at only one locality in the State, the City quarry at Raleigh, where they number less than half a dozen in all. They do not exceed 6 inches in width, and most of them are not more than 2 inches. Some of them are in contact with pegmatite on one side and the inclosing granite on the other. Megascopically, the aplite is very light in color, being composed of a fine-grained crystallization of quartz and feldspar, through which are irregularly distributed subordinate minute flecks of black biotite.

Microscopically, the aplite is strikingly similar in mineral composition to the inclosing granite, except that it is much finer grained and contains a much smaller proportion of biotite and plagioclase feldspar. The mineral composition places it with the potash aplites.

QUARTZ VEINS.

Quartz veins of small dimensions cut the granite in a number of quarries, usually where pegmatite intrusions are strongly developed. The two sets of intersecting bodies are more or less closely associated. The quartz veins are not numerous in any of the openings, and as a rule they do not measure more than a few inches across.

Quartz veins of large dimensions are numerous over the crystalline area of the State. Many of them are readily traced over the surface for considerable distances by the partly disintegrated outcrops and the abundant fragments which litter the surface. In cross section they vary from 25 feet to several hundred yards. In some localities the veins form true fissure veins, are metalliferous, and mark many of the most important gold and copper mines in North Carolina

RELATIONSHIP BETWEEN THE JOINTING AND THE BASIC DIKES.

Careful measurement and tabulation of the vertical joints and the dikes of basic igneous rocks show a marked parallelism in certain directions between the joints and dikes. The planes of most of the joints and the strikes of most of the dikes are in the northeast and northwest quadrants. Moreover, in nearly every quarry where basic dikes are exposed the strike of the dikes and that of the joints for a given direction is coincident, apparently indicating that in those places, at least, the jointing has exercised some influence on the cutting direction of the dikes. Not only is this true for the dikes penetrating the granite in the quarries, but it is also true of the Triassic sandstone belt, where the same relation between the joints and the dikes is shown. Whether this statement will apply in general to the dikes beyond the limits of the fresh-rock exposures it is not possible to say, as the jointing is entirely obscured by the deep residual decay covering the fresh rock, but presumably it does.

Probably the basic dikes, so far as they have been observed, do not belong to a single period of intrusion but are to be referred to different ages. The observations recorded denoting coincidence in the directions of dike and joint include both the massive, unaltered, igneous intrusive rock and the perfectly schistose, more or less altered, basic dike. If these observations are correct, clearly the jointing in the granites preceded the intrusion of the basic rocks forming the dikes.

INDIVIDUAL QUARRY AREAS.

EVEN-GRANULAR GRANITES.

DISTRIBUTION.

Granites of even-granular type have wide distribution and compose the bulk of the granites occurring in North Carolina. They range from massive to partly schistose rocks, are fine to medium in texture, rarely coarse, and are pink to gray in color, the prevailing color being light to medium and dark gray.

Mineralogically, the even-granular granites are mixtures of potash feldspar (orthoclase chiefly, with variable microcline), palgioclase (oligoclase or albite), and quartz, with a variable quantity of biotite and, in several areas, some additional hornblende as the characterizing accessories. The prevailing large amount of plagioclase feldspar in the rocks is a noteworthy feature; rarely does this constituent sink to very subordinate proportions; usually it is approximately equal to or even exceeds the potash feldspars. In many areas the poverty of the rocks in the ferromagnesian constituent is a striking feature, a fact well illustrated in the extensive and important granite area known as Dunns Mountain, in Rowan County.

The even-granular granites are described below under (1) Coastal Plain granites; (2) Piedmont Plateau granites; and (3) Appalachian Mountain granites.

COASTAL PLAIN GRANITES.

GENERAL STATEMENT.

In places near the boundary between the Coastal Plain with the Piedmont Plateau, but extending well within the Coastal Plain, the thin veneer of loose unconsolidated sands and gravels has been stripped from the surface, exposing small, irregular, somewhat elongated areas of the crystalline rocks. Many of these areas are composed either wholly or in part of granites of good quality. This stripping of the Coastal Plain sediments from the crystalline rocks has taken place mostly along the courses of the larger streams. In such areas the granitic rocks are usually exposed in ledge and bowlder form and as flat-surfaced masses, a short distance back from the stream.

Some of the schists and gneisses composing parts of the inliers of crystalline rocks are derived from original igneous masses. They include both acidic and basic types.

The principal areas of even-granular granite lie in Wilson, Edgecomb, and Nash counties to the east of Raleigh. In each of these counties small openings have been made in the granites and some of the rock has been quarried for local use. None of the openings, however, are sufficiently large to be called quarries, and no systematic work has yet been undertaken, though the granite is of good quality, is readily accessible, and can be easily worked.

The rocks are massive biotite granites, in one place hornblende bearing, varying from fine to coarse grained in texture and from gray to pink in color. Jointing is usually well developed, intersecting the rock in three general directions—northwest, northeast, and north-south. The granites are younger than the schists and gneisses into which they have been intruded, as shown by the nature of the contacts, in the partial decay of the rocks, and by their massive structure as contrasted with the completely schistose structure of the surrounding rocks.

The granites of the North Carolina Coastal Plain region occur in three principal areas—(1) the Contentnea Creek area; (2) the Elm City area; and (3) the Rocky Mount and Springhope area.

DESCRIPTIONS OF QUARRY AREAS.

CONTENTNEA CREEK AREA.

About 3 miles south of Wilson granite is exposed in large bowlders and flat-surfaced masses for several miles along and near Contentnea Creek. A small opening was made some years ago near the creek where it is crossed by the Wilmington and Weldon Railroad.

The rock is a biotite granite of pinkish-red color and coarse grain, with a marked porphyritic tendency. Feldspar is largely in excess of the other minerals. The larger feldspar individuals are 1 to 2 inches long and are pinkish in color, exhibiting good cleavage development and twinning on the Carlsbad law. The feldspathic constituent has been estimated to amount to 82 per cent, proportioned as follows: Orthoclase, including a little microcline, 50 per cent; plagioclase (albite), 32 per cent. Quartz is the next most abundant mineral. Biotite is only sparingly present and is largely altered to chlorite. Accessory apatite and magnetite and secondary kaolin, calcite, and a light-colored mica are present.

The vertical joints strike N. 50° E., N. 70° W., and north-south. No veins nor segregations were observed. The granite takes a good polish.

ELM CITY (TOISNOT) AREA.

The Elm City area is located in the extreme northern part of Wilson County, 3 miles north of Elm City. The granite is exposed in the form of bowlder outcrops, and one opening has been worked to an average depth of about 30 feet. The decayed granite, which requires stripping for the quarrying of fresh rock, averages 6 to 8 feet in depth.

The rock is a biotite granite of light-gray color and medium-coarse grain. The minerals are potash feldspars (orthoclase and a little microcline), much soda-lime feldspar (very acidic oligoclase), quartz, and biotite with occasional hornblende, together with accessory zircon, apatite, a little titanite, and ilmenite and secondary chlorite, kaolin, and light-colored mica.

The vertical joints, rather closely spaced, strike N. 40° E. and N. 80° W. and have slickensided surfaces. A dike of very fine grained amphibolite schist carrying much pyrite penetrates the granite, striking approximately northwest and southeast and ranging from 4 to 20 feet in thickness. Quartz veins trending north and south also cut the granite. Two of these veins, observed on the west side of the quarry, are about 12 inches wide and are wrapped with films of hornblende.

The poor working qualities of the granite, coupled with the close jointing and the numerous veins, render the stone unsuited for general constructional purposes.

ROCKY MOUNT AND SPRINGHOPE AREA.

About a mile north of Rocky Mount, in Edgecombe County, bowlder outcrops and small flat-surfaced exposures of granite can be traced along Tar River for some distance westward into Nash County. The granite is associated with crystalline schists which were derived in part from original igneous rocks. Contacts between the granite and the schists were not observed, but the field evidence clearly suggests that the granite is the younger rock.

At the cotton mill on Tar River, 1 mile north of Rocky Mount, several small openings were made in the granite some years ago. The rock is a biotite granite of gray color and medium grain. Its minerals are potash feldspars (orthoclase and microcline in about equal amount), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with accessory apatite, zircon, and magnetite and secondary chlorite and epidote.

The vertical joints strike northeast-southwest, N. 30° W., N. 80° W., and north-south. The joints cut the granite at intervals which vary from only a few inches in some places to many feet in others. Pegmatite dikes, ranging in thickness from a fraction of an inch to more than 6 inches, intersect the granite. All gradations exist between veins containing mostly feldspar to those containing mostly quartz.

PIEDMONT PLATEAU GRANITES.

GENERAL STATEMENT.

The North Carolina Piedmont region is composed of a number of belts, approximately parallel to one another and crossing the State in a general northeast-southwest direction (Pl. XIII), composed as a rule of unlike rocks of different ages.

The granites and gneisses of commercial importance in North Carolina are most widely distributed within the Piedmont Plateau region, where they occur in considerable variety and abundance. They are biotite bearing, with additional hornblende in several areas, and muscovite in very subordinate amount if present at all. Some shade of gray prevails, though pink is largely characteristic of certain areas.

In most places the granite is of good quality and readily accessible, and as a rule it can be easily worked. Numerous quarries have been opened over many parts of the plateau region, to which the granite industry of the State is confined almost exclusively.

The Piedmont Plateau granites are described below under four geologic divisions—(1) the northeastern Carolina granite belt, comprising the counties of Wake, Franklin, Vance, Granville, and Warren; (2) the metamorphic slate and schist and volcanic belt; (3) the central granite belt, including Mecklenburg, Gaston, Cabarrus, Iredell, Rowan, Davie, Davidson, Forsyth, Guilford, and Alamance counties; and (4) the western gneiss belt, comprising the counties of Surry, Wilkes, Alleghany, Alexander, and Cleveland.

NORTHEASTERN CAROLINA GRANITE BELT.

INTRODUCTORY STATEMENT.

The position and limits of the northeastern Carolina belt are shown on the map (Pl. XIII). It comprises parts or the whole of five counties, located in the extreme northeastern portion of the North Carolina Piedmont region, extending northward from Raleigh. With but few exceptions the granites show a partial schistose structure. Biotite, the chief accessory mineral, is variable in quantity, imparting accordingly either a light or a dark gray color to the rock. In places the feldspars are of a pronounced pinkish hue and with the subordinate amount of biotite present the rock assumes more or less of a mixed pinkish-gray color. The granites are prevailingly even granular, though a porphyritic tendency is somewhat emphasized in places They do not differ essentially in mineral composition, although hand specimens of the granite from different portions of the area may show no resemblance to each other.

FRANKLIN COUNTY.

Granite exposures are numerous over the middle and eastern portions of Franklin County, especially in the vicinity of Louisburg, the county seat. Usually the rock is deeply decayed, though fairly fresh granite is exposed in large bowlder outcrops and small irregular surfaced masses. Porphyritic granite occurs at one or two places. Quarries have not been opened at any locality in the county, but several small openings have been made along Tar River at Louisburg for stone to supply a local demand.

The rock is a biotite granite of light-gray color and even, fine to medium-coarse grain. In places the feldspars have a pronounced pinkish tint, imparting a similar color to the granite. The minerals are orthoclase, microcline, acidic plagioclase, quartz, biotite, muscovite, apatite, zircon, iron oxide, chlorite, and kaolin. Orthoclase is the dominant feldspar, with little microcline but much acidic plagioclase. A thin section from a specimen 3½ miles west of Louisburg differed in composition from that above given in the absence of microcline and in containing a smaller amount of plagioclase.

The vertical joints are spaced at irregular intervals, close together in some places, but as a rule sufficiently far apart to yield dimension stone. On the road near the Louisburg bridge the joints strike N. 80° E., N. 20° W., and north-south.

GRANVILLE COUNTY.

Granite bowlders of light-gray color and medium grain occur in the vicinity and to the east of Oxford, the county seat of Granville county. No quarries have been opened, but some of the larger bowlders have been split and used locally for curbing and foundation stone and for other purposes.

VANCE COUNTY.

The granite of Vance County is perhaps among the best known in North Carolina, and some of the quarries compare favorably with the most extensive ones elsewhere in the State. The area is a large one, confined principally to the central and eastern parts of the county. Quarries are worked at several places in the county along the Seaboard Air Line Railway, chiefly at and near Greystone and Middleburg stations. The quarries at Greystone have been worked almost continuously since they were opened, about thirty years ago. Those near Middleburg have only recently been opened. Several years ago a little of the granite was quarried at Henderson, the county seat, for use on the streets.

The granite has been used mostly for street purposes in the form of blocks, for coping and bridges, and to a less extent as a building stone. It has been shipped to numerous places in Virginia and

North Carolina, especially in the eastern parts of the two States. The quarry waste is used for macadam and ballast.

Greystone area.—The Greystone quarries, located at Greystone, a station on the Seaboard Air Line Railway, are the largest and best known in eastern North Carolina. As shown in the individual descriptions, the rock is a schistose granite that is admirably suited for street purposes, for which there has been a large demand over the eastern Carolina-Virginia territory.

The principal quarries are the Old Greystone, New Greystone and those of the Greystone Granite and Construction Company and the Seaboard Air Line Railway.

The rock is a biotite granite of gray to pinkish-gray color and fine to medium grain. The schistose structure, apparent in the hand specimens, is usually indicated in the thin sections. Orientation is less apparent in the light-colored minerals than in the biotite. The principal minerals are orthoclase, microcline, plagioclase (oligoclase), quartz, biotite, a little muscovite, zircon, and apatite. Much chlorite and kaolin and a light-colored mica are developed from the alteration of the biotite and feldspars. The feldspars are more or less clouded from irregular patches and areas of kaolin and minute scales of a light mica. Intergrowths of quartz and feldspar are frequent.

The *Old Greystone quarry*, the largest in the county, is located near the depot at Greystone and was continuously worked for fifteen years from the date of opening, about thirty years ago. The quarry opening covers about 2 acres and is worked to an average depth of 35 feet.

The rock is a foliated biotite granite of fine grain and pronounced porphyritic tendency. It is dark gray in color, with a pinkish cast imparted by the prevailing pink-colored feldspars.

The decayed granite at the surface, including soil, averages about 3 feet in thickness, but is as much as 15 feet in places. Near the top of the opening the granite weathers into thin horizontal sheets, which become much less well defined lower down, attaining near the bottom a thickness of 12 feet or more. Vertical joints striking N. 60° E. cut the granite at irregular intervals, in some places being spaced close together, in others at wide intervals. Slickensides are developed on the surfaces of the joints. Dikes of pegmatite and of fine-grained granite are somewhat numerous, varying in thickness from a fraction of an inch to many inches and conforming as a rule to a north-south direction. Small, irregular, roughly rounded, dark-colored segregations (knots) chiefly of biotite occur here and there.

The *New Greystone quarry*, opened in 1902, is about 150 yards west of the Old Greystone quarry. It averages less than 12 feet in depth. The fresh rock is covered to a depth of 3 to 6 feet with soil and decayed granite.

The rock is a biotite granite similar in all respects to that of the Old Greystone quarry, except that the schistosity is less marked. The vertical joints strike N. 5° to 10° E. and N. 60° E. Occasional small grains of pegmatite cut the granite.

The *Greystone Granite and Construction Company's quarry* is about three-fourths of a mile northwest of the depot at Greystone. The hill slope back of the quarry rises about 25 to 30 feet above the opening. The quarry was first opened in 1889 and was worked constantly for about six years, but has been idle for some time. At the time of working it was well equipped with the necessary modern machinery for quarrying and handling the stone, and a spur track was laid and operated between Greystone and the quarry. The opening is a large one; it averaged nearly 250 feet each way and was worked to a depth of about 25 feet.

The opening shows along the face a zone of decayed material from the surface downward for 2 to 10 feet, composed largely of a granite soil of red to light-gray color and thin, partly decayed, nearly horizontal sheets of moderately firm rock. As in the Old Greystone quarry, the horizontal parting planes are less well defined down in the fresh rock, although they are variable, separating the rock into layers or sheets 8 or 10 feet thick.

The granite is essentially the same as that of the Greystone quarries already described. It is somewhat lighter in color, but has a pinkish tone. It ranges from fine to medium grain in texture and is distinctly schistose in a general north-south direction. The feldspars average larger than the other mineral constituents, are white or of light color, and show the usual porphyritic tendency.

Two sets of vertical joints of about equal development and intersecting at right angles cut the granite in approximately north-south and east-west directions. These are spaced sufficiently far apart to admit the quarrying of blocks of any desirable size. Pegmatite dikes 6 to 8 inches across penetrate the granite and strike in a general north-south direction. Small irregular knots of black mica are noted here and there in the rock.

The *Seaboard Air Line Railway quarry* is about 2 miles northeast of Greystone station. In all several acres of surface has been stripped to a moderate depth over the gentle slopes on both sides of a small stream. The quarry was opened about 1896. A spur track is laid from the main line near Greystone to the quarry, a distance of about 1⅛ miles.

Three rather strongly contrasted phases of the granite are developed in the quarry. One, which comprises the main body of the rock, is the typical granite of the Greystone area, dark gray with a faint pinkish tone and generally fine grained. In the hand specimens the schistose structure is much less marked than in the Greystone rock proper, and it exhibits a pronounced porphyritic tendency. Another phase is a medium-textured, uniformly light-pink granite containing a much smaller amount of biotite than the phase just described. The rock is decidedly schistose in structure and highly feldspathic, and the biotite is distributed along roughly parallel disconnected bands of knife-edge thickness. As nearly as could be determined, the width of this zone as exposed in the opening is not less than 600 feet, with a north-south direction. The porphyritic tendency is not shown in this phase of the granite. A third phase is a dark blue-gray biotite granite, generally finer grained than the other two and containing a larger amount of biotite. This phase of the rock is usually developed between the pink and the gray granite as a narrow zone from 2 to 6 feet across.

The three phases of the granite are alike schistose in structure, the schistosity striking north and south; and the jointing is likewise continuous through them in the same general directions. The quarry is not sufficiently developed to show conclusively the exact relations and significance of these three variations in the rock, but such data as were available seemingly indicate that they are phases of the same rock and not separate intrusions. The differentiation was possibly begun with the cooling of the magma and completed by the intense dynamic metamorphism to which the granite has been subjected. Indeed, banding on a small scale, due to metamorphism, differentiating the rock into dark and light-colored bands, is distinctly noticeable in some parts of the quarry.

Vertical joints intersect the granite, striking north-south, east-west, and northwest-southeast. The joints in the east-west direction form the major set and their surfaces are usually slickensided after the fashion of those in the Old Greystone quarry described above. Pegmatite dikes varying from 1 inch to more than 6 inches across and mostly striking N. 10° E. are numerous.

The stone quarried from this opening is reported to have been used for ballast and for street purposes.

One other exposure of the granite near Greystone station, between the main track of the railroad and the New Greystone quarry, was recently opened to a small extent, but was soon abandoned on account of the numerous veins and the irregular texture of the rock.

Middleburg area.—Two quarries, near together, have been opened on the west side of the Seaboard Air Line Railway, 1 mile west of Middleburg station and about 3 miles north of Greystone. The granite is essentially the same as that quarried at Greystone. On the whole it probably contains a very little more biotite and is correspondingly darker. The feldspars are chiefly light in color—nearly white, with the barest pinkish cast. The rock is fine grained, displaying a marked porphyritic tendency in the feldspathic constituent. The biotite is distributed in fine black shreds along parallel lines arranged in the direction of their longer axis. Hand specimens from the two openings are indistinguishable.

The rock is a biotite granite, distinctly schistose, and composed of the same minerals in practically the same proportions as the granite at Greystone. Feldspar predominates, consisting of the potash varieties, orthoclase and microcline, with microperthitic intergrowths, and an acidic plagioclase. Some alteration to kaolin and muscovite is indicated in the cloudy and opaque areas over the feldspar surfaces. Micropoikilitic structure in the potash feldspars is common and Carlsbad twinning is occasionally observed. Intergrowths of quartz and feldspar, indicating the overlapping of the periods of separation from the magma of these two minerals, are common. Biotite is largely altered to chlorite and it is identical in occurrence and microscopic properties with that in the granite at Greystone. The microscopic accessories are the same in the granite from the two areas.

The first quarry was opened in 1899. The opening averages about 400 by 199 feet, and has been worked to an average depth along the quarry face of 25 feet. A 22-foot quarry face is developed lengthwise of the opening, covered at the top by an average depth of about 4 feet of soil derived from the decay of the granite.

Only one set of joints cuts the granite; they strike east and west, and are spaced some distance apart, less than half a dozen planes being visible in the entire quarry. Very few seams were noted. A tendency toward banding is indicated in places, separating the rock into alternating darker and lighter layers in a direction N. 20° E., which is the prevailing strike of the schistosity.

The rock is a biotite granite of dark-gray color and fine grain. It contains perhaps a slightly larger proportion of biotite than that quarried at Greystone. The feldspars are mostly white and show much less of the pink color so characteristic of the former area.

A second opening was made in 1903 in an outcrop of the same granite 100 yards south of the quarry described above. The jointing and schistosity are the same in the two openings.

WAKE COUNTY.

The principal exposures of granite in Wake County in which openings have been made are in the Raleigh area and the Wyatt-Rolesville area.

Raleigh area.—The only quarries worked in the Raleigh area are within the eastern limits of the city of Raleigh, about 1½ miles from the statehouse. Two large openings near together were first made more than seventy-five years ago. From 1833 to 1836 stone was quarried to build the statehouse. The north opening, which is the larger, is 850 feet long in a north-south direction, 75 feet wide, and 30 to 35 feet deep. The south opening is 330 feet long, 75 feet wide, and 25 feet deep.

The rock is a biotite granite of medium-gray color and even, fine grain. It is not entirely massive, but displays a partial schistose structure. The minerals are the potash feldspars (orthoclase and microcline in nearly equal amounts), an excess of acidic plagioclase, quartz, black mica (biotite), and a little white mica (muscovite), together with accessory apatite and zircon and secondary chlorite, epidote, and colorless mica. Intergrowths of the feldspar and quartz are common. Peripheral granulation of the quartz and feldspar is indicated, being a result of mechanical stress or pressure. A partial chemical analysis of this granite is given on page 117.

An average depth of about 3 feet of deep red clay derived from the decomposition of the granite is exposed at the top of the openings. Below this is a zone of less advanced decay, 10 feet thick, exposing partly decayed granite in thin sheets. Within this zone the rock along the horizontal parting planes and the vertical joints is broken down into light-red granitic clay and the middle portion of the sheets is composed of moderately hard though deeply decayed granite. Below this second zone of weathering the granite is hard and fresh to the depth of working.

Joints occur at fairly close intervals, but the planes are not so close as to prevent the quarrying of dimension stone. The principal joints strike approximately east and west and their surfaces are slickensided.

Pegmatite dikes up to several feet in thickness are very abundant. Dimension stone free from these dikes can not be obtained, as attested by the stone used in the statehouse. Slight faulting is shown in some of the dikes, with an extreme displacement of 6 inches. A single dike of banded aplite-pegmatite was observed. Thin sections show it to be a potash aplite.

Along the west side of the north opening is a large diorite mass sharply defined from the granite and cut in all directions by pegmatites and true granite veins, much crumpled and contorted. The pegmatites are largest in the diorite mass but are large also in the granite on the east side of the quarry. The line of contact between the granite and the diorite seems to be sharp but exceedingly irregular. The exact relations between the diorite and the granite were not plain. Thin sections show the rock to be a quartz diorite, composed of the principal minerals hornblende, plagioclase feldspar, and quartz.

At the state prison, 1½ miles west of the capitol, a quarry 300 to 350 feet in diameter and worked to a depth of 60 feet was opened in 1868 to furnish stone for the foundations and walls of the prison building. The rock is a biotite granite gneiss of irregular color and texture. The vertical joints strike N. 80° W. and north-south.

Wyatt-Rolesville area.—The Wyatt-Rolesville granite area is about 14 miles north of Raleigh and about 4 miles south of Wake Forest, extending eastward from Wyatt, a station on the Seaboard Air Line Railway, to Rolesville, a distance of about 5 miles. Flat-surfaced outcrops several acres in extent are exposed near Wyatt station and near Rolesville. As indicated below, the granite is biotite bearing, but differs in some respects from that farther south in the Raleigh area. No quarries have been opened.

The rock is a biotite granite of light-gray to pinkish-gray color and fine to medium grain. Muscovite is more plentiful in the granite at Wyatt station and the feldspar is of a pinkish cast over the entire area. Thin sections of the granite near Rolesville showed the minerals to be orthoclase, microcline, acidic plagioclase, biotite, occasional muscovite, apatite, and zircon and secondary chlorite, kaolin, and iron oxide. Microcline is variable in quantity, nearly equaling the orthoclase in one section. Plagioclase nearly equals potash feldspar in amount in some sections and is considerably less in others.

Pyrite and garnet are both present in the granite at Wyatt, the latter locally in considerable quantity. Pyrite appears also in the granite at Rolesville. Vertical joints in the granite at Wyatt strike N. 20° E., N. 80° E., and north-south, and at Rolesville N. 20° E. and east-west. The spacing between the joints varies but is usually sufficiently great to yield dimension stone. Pegmatite dikes ranging in thickness from a fraction of an inch to several inches cut the granite in places.

WARREN COUNTY.

The most important exposures of granite in Warren County are found at Warrenton, the county seat, and to the north and northwest of Wise siding, on the Seaboard Air Line Railway. Some stone has been quarried in each locality.

Near the west limits of Warrenton an irregular dark-gray biotite-hornblende gneiss has been quarried for local use. It is not a desirable rock for any but the rougher grades of work. Vertical joints strike N. 60° E. and N. 30° W. Scattered crystals of pyrite are noted in the rock.

About a quarter of a mile east of the Richmond division of the Seaboard Air Line Railway, 1 mile northwest of Wise siding, a muscovite-bearing biotite granite is quarried for general building and street purposes.

The rock is a medium light-gray massive biotite granite of medium grain. Biotite is regularly distributed through the rock; much red garnet is present in places, and, indeed, is so abundant in some of the hand specimens that it imparts a mixed pink and gray color to the rock. The principal minerals are potash feldspar (orthoclase and and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and a little muscovite, together with the accessories apatite, zircon, titanite, and rutile and secondary chlorite and light-colored mica.

About 2 miles north of Warren Plains a small opening was made some years ago in a light-colored muscovite granite. It is of even, fine-grained texture, and is composed of orthoclase, much acidic plagioclase, a little microcline, and muscovite. Some garnet and iron oxide occur. The vertical joints strike N. 10° E., N. 45° E., and N. 60° W. and are too closely spaced, as a rule, to permit the quarrying of reasonably good dimension stone.

SUMMARY OF GRANITES OF NORTHEASTERN CAROLINA BELT.

Within the five counties composing this belt there are large workable areas of different grades of granite suited for nearly all classes of work in which granite is used, except for monumental stock. Systematic quarrying has been limited chiefly to areas in two counties—the Raleigh area in Wake County and the Greystone and Middleburg area in Vance County. Granite outcrops are fairly numerous and are usually of sufficient size to admit of quarries being opened without much surface stripping. The vertical joints are rarely spaced so close as to prevent the quarrying of dimension stone. Pegmatite dikes are so abundant in one or two localities as to make it impossible to obtain dimension stone free from them.

The granites show but slight variation in mineral composition over the entire belt. With one exception they are biotite granites containing occasional muscovite and, in two places, hornblende. They range from fine to medium grained in texture, with a porphyritic tendency in places. Structurally they vary from massive to schistose rocks. In color they are some shade of gray, with a pronounced pinkish tone, imparted by a pink feldspar, over much of the area.

METAMORPHIC SLATE AND VOLCANIC BELT.

The belt composed of metamorphic slates and schists and altered volcanic rocks extends in a general southwesterly direction across the middle portion of the State and forms a part of the eastern Piedmont region. Its width varies from 8 to 50 miles. It is included between the Carolina igneous belt on the west and the Triassic belt, chiefly, on the east.

Rocks of granitic composition and texture have been noted in only one county (Orange) within this belt. The principal exposures occur a short distance to the north, south, and east of Chapel Hill. They are biotite granites with much variation in color, texture, and structure. Nowhere has the rock been quarried, and except for certain grades of rough work it seems to be of doubtful commercial value.

CAROLINA IGNEOUS OR MAIN GRANITE BELT.

INTRODUCTORY STATEMENT.

The main granite belt of North Carolina, as shown on the map (Pl. XIII), occupies a nearly central position in the Carolina portion of the Piedmont Plateau. It crosses the State in a general northeast-southwest course, beginning at a point east of Danville, Va., and extending southwestward into South Carolina. In width it probably averages from 15 to 50 miles. It is traversed for most of its length by the main line of the Southern Railway and is crossed at rather close intervals by many of the principal railroads which join the main line of the Southern, being thus one of the most accessible areas in the State.

The southeast border of the belt can, as a rule, be traced with comparative readiness along an irregular line marking the contact with the belt of metamorphic slates and volcanic rocks. On the northwest it is bounded by an extensive belt of gneisses and schists of the western Piedmont region, and the line of differentiation between the two belts is less easily determined.

Granite and diorite constitute the two principal rock types of this belt. These may be either massive or more or less mashed, squeezed, and schistose. They are penetrated by dikes of granite and diabase and other basic intrusive rocks. Areas of variable schists are scattered over the belt, in many places forming the country rock.

The area is further traversed by very many intersecting quartz veins, large and small. These are usually concealed by the deep covering of rock decay, but their abundance is indicated by the innumerable angular fragments of quartz strewn over the surface.

Two phases of the granite are prominently developed over many parts of the area, the porphyritic and the even granular, which nearly everywhere grade into each other. A zone of porphyritic granite extends in a northeasterly direction through a number of counties along the western margin of the belt. This zone and other areas of porphyritic granite in the igneous belt are described on pages 164–170. With only one or two exceptions the even-granular granites are biotite granites of some shade of gray, and they vary from fine to coarse in texture.

Some of the largest and most important granite areas in the State are included in the Carolina igneous belt. As a rule, the rocks are deeply decayed, but outcrops of nearly fresh granite occur in every county within the belt. The decayed material is in general characteristic of the underlying rocks from which it has been derived, and the granites can thus usually be traced with considerable accuracy by means of the overlying soil.

The belt includes either the whole or a part of each of the following counties, named in order from south to north: Gaston, Mecklenburg, Cabarrus, Rowan, Iredell, Davidson, Davie, Forsyth, Guilford, Alamance, and Caswell. Granite has been quarried to some extent in each of these counties except Caswell.

GASTON COUNTY.

Numerous exposures of granite occur in the central and middle eastern portions of Gaston County. The rock is usually deeply decayed, yielding a characteristic light-gray soil, by which the granite is readily traced.

The rock is a biotite granite of light to medium dark-gray color and fine to medium-coarse grain. At Belmont the granite has a decided pinkish cast. With only few exceptions, the granites over most of the area show a pronounced porphyritic tendency. The principal minerals are potash feldspar (orthoclase and microcline, usually in nearly equal amount), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory apatite and zircon and secondary chlorite, epidote, and a light-colored mica. Soda-lime feldspar is lacking in some thin sections of the granite near Gastonia, but is present in large amount in the granite near Belmont.

The granite has been quarried for local use from numerous small openings in and near Gastonia and from a small opening 3 miles northwest of Belmont, a station on the Southern Railway 10 miles south of east from Gastonia. As measured in the openings, the vertical joints show the strike of N. 20° to 30° E., N. 40° to 60° E., N. 60° to 70° W., N. 80° W., north-south and east-west. Usually not more than two sets of joints are developed in any one of the openings, and in several only one set was observed. The joints are sufficiently far apart to permit dimension stone to be quarried. Slickensides are developed on the surfaces of the joints at the opening 3 miles northwest of Belmont.

A few knots of small size occur, and in several openings pegmatite dikes 1 to 2 inches thick were observed.

MECKLENBURG COUNTY.

Granite occurs very generally over Mecklenburg County, but comparatively few quarries have been opened. The areas in which some granite has been quarried are the Charlotte area, the Morning Glade Church area, and the Davidson area.

Charlotte area.—The Charlotte area includes all known granite localities within a radius of 5 or 6 miles of the city of Charlotte. Openings have been worked within and just beyond the city limits at several places about 4 miles to the east; at Belmont Springs, also on the east; and at several places about 5 miles to the south.

The *City quarry,* located near the freight depot in the southeastern part of Charlotte, is 350 by 400 feet and is worked to a depth of 50 feet. The rock is too extensively crushed and jointed and too variable in color and texture to be used for any purpose except for road metal and ballast. The product is used principally for macadamizing the city streets in Charlotte.

The rock is a biotite granite of bluish-gray color and generally of fine grain. Potash feldspar (orthoclase and microcline) and very little plagioclase compose the feldspar content. Two principal sets of vertical joints, striking N. 40° E. and N. 35° to 50° W., cut the granite at close intervals. The joint surfaces are slickensided. A series of dark-greenish, schistose, fine-grained diabase dikes, varying from 12 inches to several feet across, cut the granite coincident with the N. 40° E. set of joints.

The *Oders quarry,* just beyond the southeastern limits of Charlotte, comprises two small openings, in a biotite granite of the same color and texture as that of the City quarry. The granite is crushed and intersected by closely spaced vertical joints, striking N. 10° W. and N. 60° W. The product can be used in the form of crushed stone.

Several small openings 4 miles east of Charlotte are near the Seaboard Air Line Railway, in a biotite granite of variable texture. The granite is more or less schistose and is cut by dikes of diabase. The product can be used only for the rougher grades of work.

Bowlder exposures of a hornblende-biotite granite occur over a large area on both sides of the Nation Ford road, 5 miles south of Charlotte. A number of small openings have been made in different places and some of the largest bowlders have been partly worked off. The rock is a hornblende-biotite granite of blue-gray color and medium grain. The principal minerals are potash and soda-lime feldspars, quartz, hornblende, and biotite, with much titaniferous magnetite. Hornblende and biotite are partly altered to chlorite. Pyrite occurs here and there. Small and large knots are so abundant in the Kirkpatrick openings as to render the stone unfit for the better grades of work.

At Belmont Springs, 1½ miles east of Charlotte, a dike of quartz porphyry, whose width nowhere exceeds 25 feet and which has been appropriately named leopardite,[a] intersects the biotite granite. It is a dense, hard, tough, and compact cryptocrystalline rock, which breaks with a conchoidal fracture. It is nearly white, tinged a faint greenish in places, and is penetrated by long parallel streaks or pencils of black color. (See Pl. XV.) When broken at right angles to the streaks the surface is dotted with rounded irregular black spots, varying in diameter from that of a pin head up to half an inch. These pencils are entirely absent from some portions of the rock and are closely crowded together in others. The rock is composed essentially of a crystalline aggregate of feldspar (potash and soda-lime varieties) and quartz, with less colorless mica. Idiomorphic phenocrysts of quartz and feldspar of small size are distributed through the groundmass. The black streaks or pencils are composed of the oxides of manganese and iron. The rock is susceptible of an excellent polish and could be used with splendid effect in inlaid work.

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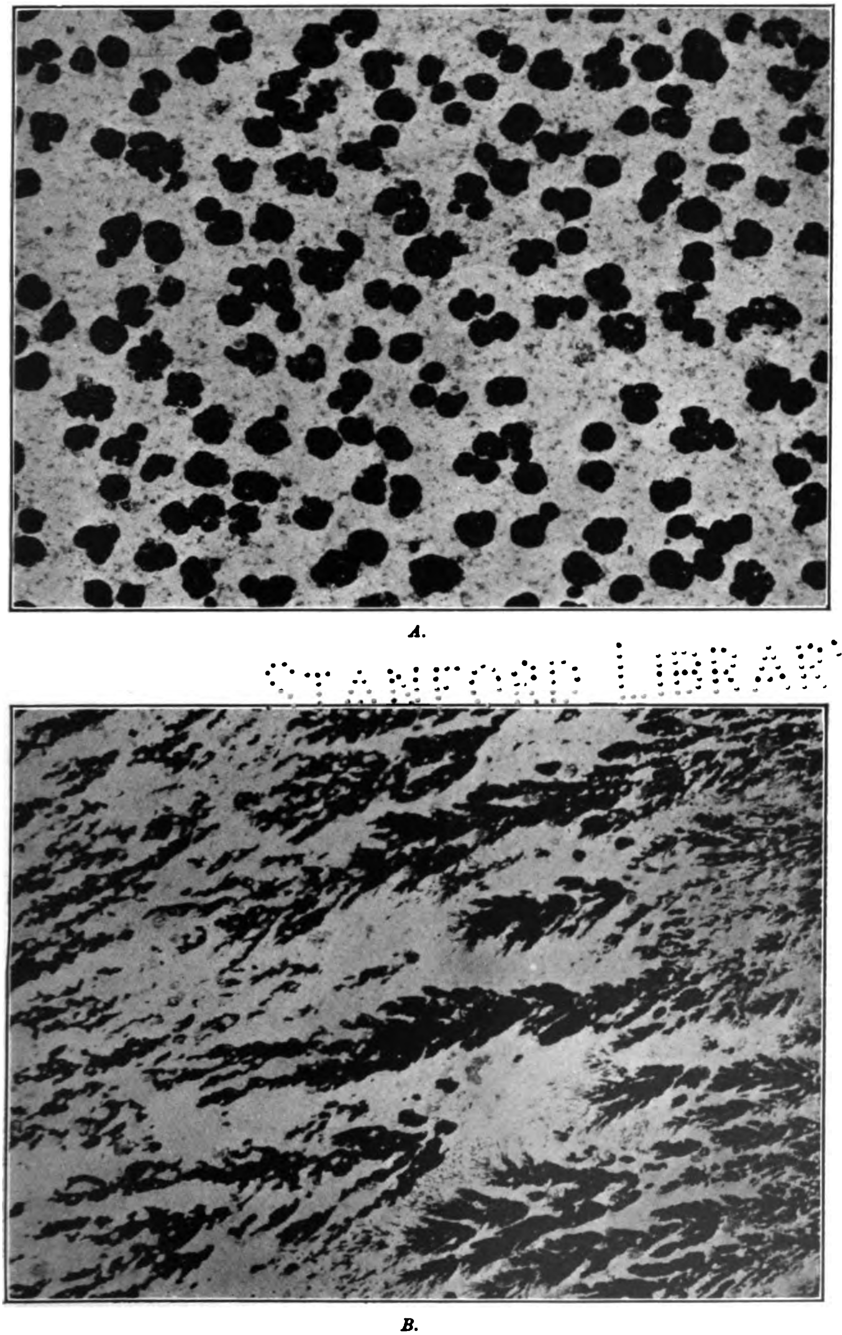
[a] Genth, F. A., Am. Jour. Sci., 2d ser., vol. 33, 1862, p. 198.

Morning Glade Church area.—The Morning Glade Church granite area is 10 miles east of Charlotte and 4 miles east of south from Newells station. One of the large bowlders on the Cross place has been quarried, and this constitutes the only development. The rock is a biotite granite of light-gray color and medium-grained texture. The largest bowlders are from 20 to 30 feet high and proportionately large in other dimensions.

Davidson area.—The Davidson granite area is located mainly in the extreme northern part of Mecklenburg County, but extends northward into Iredell County and eastward into Cabarrus County. Numerous small openings east, south, and southwest of Davidson have been made at different times to obtain stone for local use, but no regular quarries have been worked. The earliest quarrying in the area was done prior to the civil war, to obtain stone for foundations, steps, and sills in the early buildings of Davidson College. The stone was quarried from the immense bowlder outcrops of biotite granite, on West Fork of Rocky River, 5 miles east of Davidson, located partly in Mecklenburg and partly in Cabarrus County.

Two varieties of granite occur in the Davidson area. The dominant variety is a biotite granite of light to dark gray color and fine to medium grain. The minerals are potash feldspar (orthoclase and microline), soda-lime feldspar (oligoclase), quartz, and biotite, with titanite, magnetite, apatite, and zircon. Epidote and chlorite occur as secondary minerals. Pressure effects are plainly visible in the granite from the various openings. At the Knox quarry four sets of vertical joints cut the granite, spaced at close intervals and striking N. 20° E., N. 45° W., north-south and east-west. The joint planes are slickensided, indicating subsequent movement in the granite mass.

The second variety is a biotite-bearing hornblende granite of medium-gray color and medium grain. It is exposed in large bowlders and low ledges along a small stream on the Caldwell place, 1 mile



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LEOPARDITE (QUARTZ PORPHYRY) NEAR CHARLOTTE, MECKLENBURG COUNTY, N. C.

A. Section across black streaks. *B*. Section along black streaks.

east of Davidson. Some of the stone was quarried many years ago for foundations in several of the Davidson College buildings. The hornblende is distributed through the rock as irregular grains and lath-shaped crystals, measuring as much as 1¼ inches long by one-fourth inch wide. The minerals are potash and soda-lime feldspars (the latter in excess), quartz, hornblende, biotite, and a little magnetite, with some secondary chlorite and epidote.

The vertical joints strike N. 70° E. and N. 20° W., and are sufficiently far apart for the quarrying of dimension stone. Numerous areas of dark-colored knots occur in places, measuring 2 to 10 inches in length by 1 to 3 inches across.

CABARRUS COUNTY.

Even-granular granites occur over many parts of Cabarrus County, but except at several small openings near Concord no quarrying has been attempted. The rock is a biotite granite varying from gray to pink in color, fine to medium grained in texture, and massive to schistose in structure. The exposures are in the form of bowlders, ledges, and flat-surfaced masses.

Four miles southwest of Concord the Balfour Granite Company opened a quarry in a large bowldery ledge outcrop of augite-hornblende-biotite syenite of dark-gray color and coarse texture (Pl. XVI, *B*). Its principal minerals are orthoclase, microcline, oligoclase, green augite (diopside), hornblende, biotite, magnetite, pyrite, and kaolin. The feldspar very largely predominates in the form of large, irregular bluish-gray grains. The opening is 150 by 225 feet, worked to a depth of 25 feet. The vertical joints strike N. 40° E. and N. 40° W., with slickensided surfaces. The stone is quarried by blasting and the product is used for ballast.

ROWAN COUNTY.

One of the most important granite areas in the State is that near Salisbury, in Rowan County. The area marks a nearly continuous ridge beginning about 4 miles east of Salisbury and extending southwestward for a distance of more than 12 miles. Numerous quarries have been worked in many places on the ridge, and the stone has been widely used in North Carolina and the adjoining States. The first quarries were opened many years prior to the civil war and quarrying has been continued at intervals to the present time. Both a light-gray, nearly white granite and a pink granite of uniform color and texture and of most desirable quality are quarried on the ridge.

Dunns Mountain area.—Dunns Mountain, 4 miles east of Salisbury, forms a part of a conspicuous granite ridge 12 to 14 miles in length, trending in a general northeast-southwest direction. The ridge character is more or less apparent throughout its course, but it becomes less well defined toward the southwest. Dunns Mountain is the northern part of the ridge and the highest point, its elevation being about 900 feet above sea level and about 150 feet above Salisbury. Similar but less elevated portions of the ridge are locally known as Phillips Mountain, 6 miles nearly south of Salisbury, and Powlers Mountain, which forms a part of the extreme southwest extension of the ridge, about 9 miles southwest of Salisbury.

Over many parts of the ridge, especially Dunns Mountain proper and Phillips Mountain (Pl. XVII, *A*), the granite is exposed in huge bowlders 10 to 30 feet high and proportionately large in the other dimensions. At other points on the steeper slopes and near the top the loose residual material has been stripped from the surface, exposing large and continuous areas of the hard and bare rock surface. At still other places, where the ridge character is less pronounced, large and continuous flat-surfaced areas of the hard, nearly fresh rock are exposed. Over the intervening areas nearly fresh granite outcrops in smaller bodies, but the rock is mostly overlain by a variable mantle of residual material, from 1 to 10 feet thick, which on account of the slope can as a rule be easily stripped. In many places the exposures are sufficiently large to yield immense quantities of granite without stripping.

Two distinct and important grades of granite are quarried—a very light gray, nearly white variety, and a decided pink or flesh-colored granite. Both have the same texture and mineral composition and are closely similar in other less important particulars. The difference in color is shown only in the northeast half of the ridge, a distance of 5 miles or more. The granite has more or less of a pronounced pinkish tone over all parts of Dunns Mountain proper, but farther south this grades into the light-gray granite. Between Dunns Mountain and the village of Faith most of the rock is light gray, although several quarries have been worked within these limits in the pink granite. From Phillips Mountain, near Faith, southwestward the granite is entirely of the light-gray color.

After a careful study of the area, the writer is convinced that the light-gray and the pink granite are phases of the same rock. The light-gray granite is as strong and durable as the pink granite, but the latter is more desirable for certain classes of high-grade work.

The granite has been extensively quarried and has had a wide use both in and out of the State. Beginning at the extreme northeast end of Dunns Mountain and extending southwestward the principal quarries are those on the north slope of Dunns Mountain, the Dunns Mountain (McCanless) quarries, the Rowan Granite Company's quarries, the Balfour Quarry Company's quarries, the Consolidated Granite Company's quarries, the Phillips Mountain quarries, and the Powlers Mountain quarries. Many other small openings have been made over the ridge, but practically no stone has been quarried from them.

Microscopically the granite is an aggregate of interlocking feldspar and quartz, through which is distributed very subordinate biotite. Plagioclase equals and in many sections exceeds the potash feldspar. Microcline is usually very small in amount. Feldspar intergrowths are numerous. Biotite is sparingly present and is usually either partly or entirely altered. Scattered grains of magnetite and garnet and a few other minor accessory minerals occur. Pressure effects are plainly marked in fine mosiacs of crushed feldspar and quartz, and in strain shadows and fractures in the larger individuals. Some of the plagioclase individuals are broken across, the parts being separated and in some places bent and curved.

On the north slope of Dunns Mountain, 4 miles east of Salisbury, a number of quarries have been worked on both sides of the Stokes Ferry road. Of these the principal ones were worked during 1908 by Hartman & Hodge and by Duncan & Floyd, chiefly for dimension stone.

The granite is of medium grain and varies in color from faint pink to light gray, nearly white. More or less pinkish feldspar is usually present. The sap or partially decayed and discolored granite is very thin. The vertical joints, which are spaced at wide intervals, strike N. 50° to 70° E. and N. 25° W. Over the summit and north slope of the mountain pronounced shear zones of crushed and laminated rock, not exceeding 2 feet in width and lying at considerable distances apart, are developed in the granite. At the picnic grounds on top of the mountain the strike of the shear zones is N. 55° E. The surfaces are usually slickensided and coated with a thin veneer of yellowish-green mineral substance, which in part is epidote. A partial chemical analysis of the granite is given on page 117.

The *Dunns Mountain (McCanless) Granite Company's quarries*, which are 4½ miles southeast of Salisbury, include 45 openings, large and small, from most of which no stone has been quarried. Quarrying has been confined to three large openings, the largest one of which is 267 by 100 feet and 30 feet deep. The sap or partly decayed granite exposed in this opening averages 12 to 14 feet in thickness. The largest dimension stone shipped averaged 14 feet long by 6 feet thick. One hundred pieces, each 6 by 8 by 2 feet, were shipped to Reading, Pa.

The granite is light gray in color, the feldspars assuming a pinkish cast in places, and is of medium grain. The two principal sets of vertical joints strike N. 15° to 20° E. and N. 30° to 40° W. The planes of both sets are slickensided and are spaced at wide intervals.

The principal use made of the stone has been in buildings, as blocks and curbing for street purposes, and as macadam and ballast. In

July, 1908, the granite was being quarried for blocks to supply a Chicago contract. It has been shipped for use to various points in the Carolinas, Virginia, and Georgia, to Reading, Pa., and to Washington, D.C. The rock works well under the hammer, takes a good polish, and is susceptible of fine carved work, as displayed in some completed pieces at the quarries.

The *Rowan Granite Company's quarries* are located within a few hundred yards of Granite Quarry station on the Yadkin Railroad, about 4½ miles southeast of Salisbury. Some 12 to 15 openings are made in different places. The two largest openings are within 200 yards of each other, they are about 200 feet long by 150 feet wide, and are worked to an average depth of 32 feet. (See Pl. XVI, *A*.) Dimension stones weighing 70 to 100 tons each, were quarried from the southwest opening, quarry No. 2, in the summer of 1903, and used in the construction of the dam across Yadkin River.

The rock is a light-gray biotite granite, more or less speckled in places with a pinkish feldspar, not so pink nor so uniformly distributed through the rock as to modify the light-gray color appreciably, except at very close range and on close scrutiny. The stone possesses good working qualities, dresses well under the hammer, and is well suited for the various uses made of it.

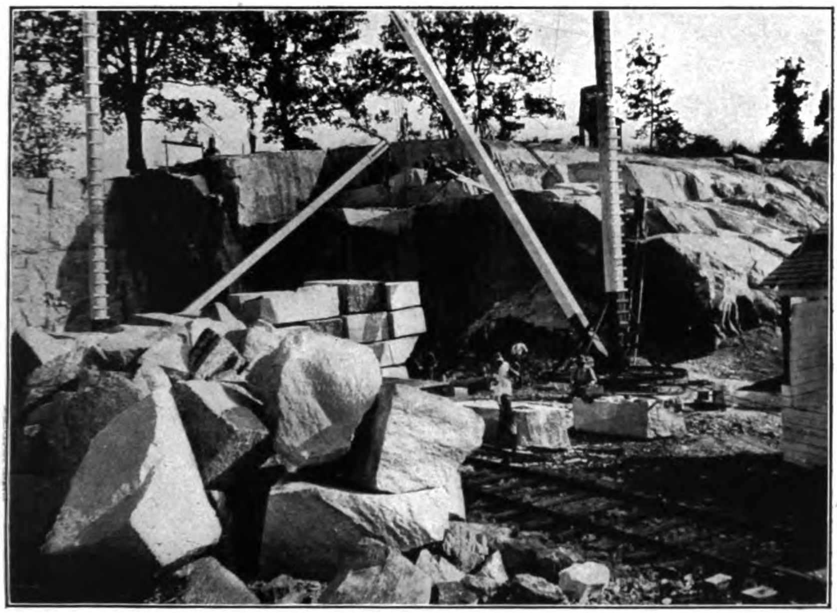
Vertical joints break the stone into polygonal blocks of different sizes, but the planes are usually spaced far enough apart to permit the quarrying of blocks of almost any dimensions. Measurements made of the strike of the joints in the principal openings gave the following results:

N. 80° E.
N. 65° E.
N. 45° E.
N. 40° E.
N. 35° E.
N. 25° E.
N. 20° E.
N. 15° E.
N. 10° E.
N. 70° W.
N. 50° W.
N. 45° W.
N. 40° W.

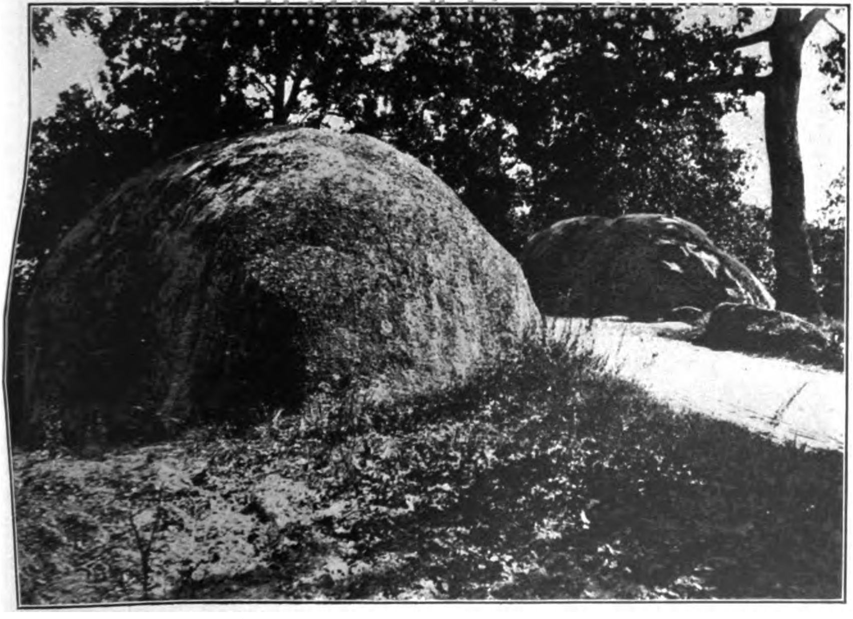
In the two large openings the joints strike as follows: Quarry No. 1, N. 40° E. and N. 40° W.; quarry No. 2, N. 35° to 45° E. and N. 45° to 50° W.

In quarries Nos. 1 and 2 the granite shows in places an advanced stage of decay, varying in depth as a rule from 5 to 6 feet, though in quarry No. 1 the granite is completely decayed at one point to a depth of more than 10 feet. The weathered material at this point consists of concentric layers of light-red and gray granitic sand and clay. The entire mass is reduced to a soft siliceous clayey material, in which the layered structure is completely preserved and which can be easily removed with the pick and shovel.

The product has been used as a general building stone, for street work in the form of curbing and blocks, as crushed stone for ballast, and to a slight extent in monumental stock. It has been shipped



A. ROWAN GRANITE COMPANY'S QUARRY NO. 2, NEAR SALISBURY, ROWAN COUNTY, N. C.



B. BOWLDER OUTCROP OF SYENITE SOUTHWEST OF CONCORD, CABARRUS COUNTY, N. C.

for use to Washington, D. C., to the most important points in Virginia and North Carolina, and to a minor extent to several other States.

These quarries were idle at the time of the writer's visit in July, 1908.

The *Balfour Quarry Company's quarries* are located less than half a mile south of the Rowan Granite Company's quarries, about 5 miles N. 20° W. of Salisbury and 2 miles northeast of Faith. Two openings have been made near together, the smaller one of which is in light-gray granite of the same color, texture, and composition as that quarried by the Rowan Company described above.

The principal opening, known as the Balfour pink quarry, is in a beautiful pink granite, in a ledge exposure having a slope of about 25°. Practically no soil covers the granite except on the east side, where slight stripping is necessary before quarrying. On the southeast side of the opening the partly discolored granite extends for several feet from the surface downward; on the north side fresh granite begins practically at the surface. Oxidation resulting in a reddish discoloration of a thin outer layer of the rock is observed along the joint surfaces.

Two sets of vertical joints strike N. 10° E. and N. 70° W. and are spaced sufficiently far apart to admit of quarrying stone of almost any size. The joint surfaces show slickensides. So far as quarrying operations have extended in depth, the rock appears to lie in sheets which vary in thickness from 2 to 10 feet, with a probable average of 8 feet. The rock contains both large and small knots of dark-gray color. The feldspar of the knots is of a pronounced pink color and in the larger segregations it shows a marked porphyritic tendency.

The rock is a biotite granite of uniform pink color and should prove to be an excellent stone for all purposes that require granite of the best grades. Its susceptibility to a high polish makes it a most desirable stone for monumental and decorative stock. The texture is medium grained and is similar to that of the light-gray granite. Biotite is very sparingly present and the feldspathic constituent, uniformly colored pink, is evenly distributed through the stone. The working qualities of the rock are excellent.

Stone from this quarry was used in the building of the Catholic University and the new municipal court building, in Washington, D. C. This grade of pink granite is in much demand in Chicago and other northern and central cities for use as monumental stock. During the summer of 1905 the nearly white granite was quarried, chiefly for use in paving, and was shipped principally to Cincinnati, Ohio. The product from this quarry was used during 1908 for monumental stock, building stone, blocks, and crushed stone.

The *Consolidated Granite Company's quarries*, 5½ miles south of Salisbury, near the village of Faith, include a large number of openings.

Quarrying is reported to have begun some years prior to the civil war. Large areas of fresh granite practically free from decay are exposed and the loose residual material, where present, is of slight depth and can be easily removed.

Two grades of granite are quarried—a light-gray granite of the same color and texture as that quarried by the Rowan Granite Company and a pink granite of the same depth of color and texture as that quarried by the Balfour Quarry Company.

Vertical joints are strongly developed in the various openings, the planes being usually spaced at intervals sufficient to allow the quarrying of stone of any desirable size. Measurements of the joints in the openings gave the following results:

N. 80° E.	N. 50° W.	North-south.
N. 40° E.	N. 40° W.	East-west.
N. 10° E.	N. 30° W.	

The *Phillips Mountain quarries* are situated on Phillips Mountain, a large, low, conical peak about 1 mile southwest of Faith, which marks the southwestward extension of the Dunns Mountain ridge. The granite is exposed over the surface of the peak in the form of huge bowlder masses in which numerous quarries have been worked. (See Pl. XVII, *A*.)

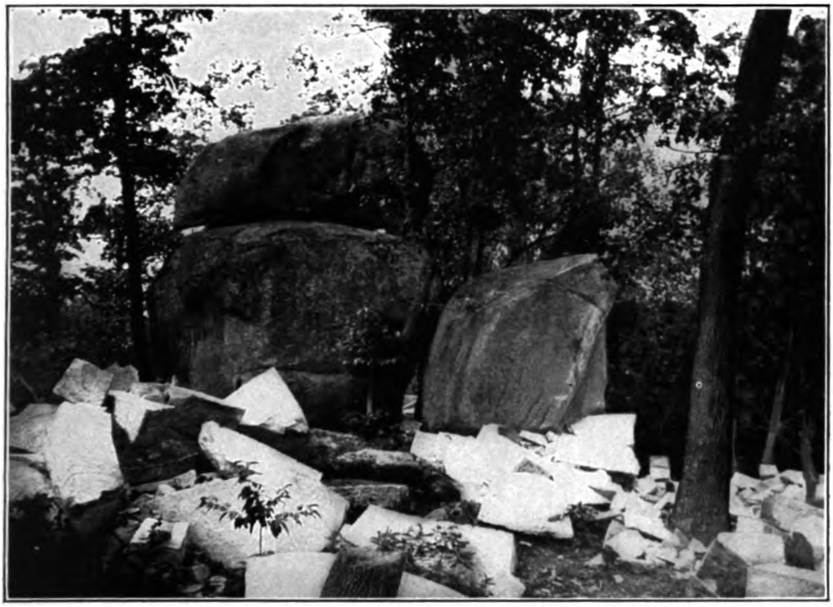
The rock is a biotite granite of very light-gray, nearly white color, and medium grain. The color and texture are fairly uniform over the area and the granite is a desirable stone for nearly all grades of work. Blocks of almost any size can be readily quarried. The stone works well under the hammer and is free from blemishes and harmful minerals.

The principal quarry operating on Phillips Mountain during the summer of 1908 was that of the Peeler Bame Company, which extracted stone for building and curbing.

The *Powlers Mountain quarries* are situated on a low dome of granite 3 miles southwest of Faith and 9 miles southwest of Salisbury, locally known as Powlers Mountain, which marks the southwest extension of the granite ridge in Rowan County. It does not exceed 100 feet in elevation above the surrounding plain. The granite is exposed in irregular hummocky surfaces, bare of loose residual material over much of the area but covered in places by a variable depth of the weathered product.

The rock is a biotite granite of light-gray color and medium grain. It is composed largely of feldspar and quartz, with very subordinate biotite.

Several openings were made in places on the slopes of the dome many years ago, and the surface raises were worked off. Examination of these ledges shows the rock to be considerably weathered, though still fairly hard and firm. The feldspars present a lusterless



A. BOWLDER QUARRY, PHILLIPS MOUNTAIN, NEAR FAITH, ROWAN COUNTY, N. C.

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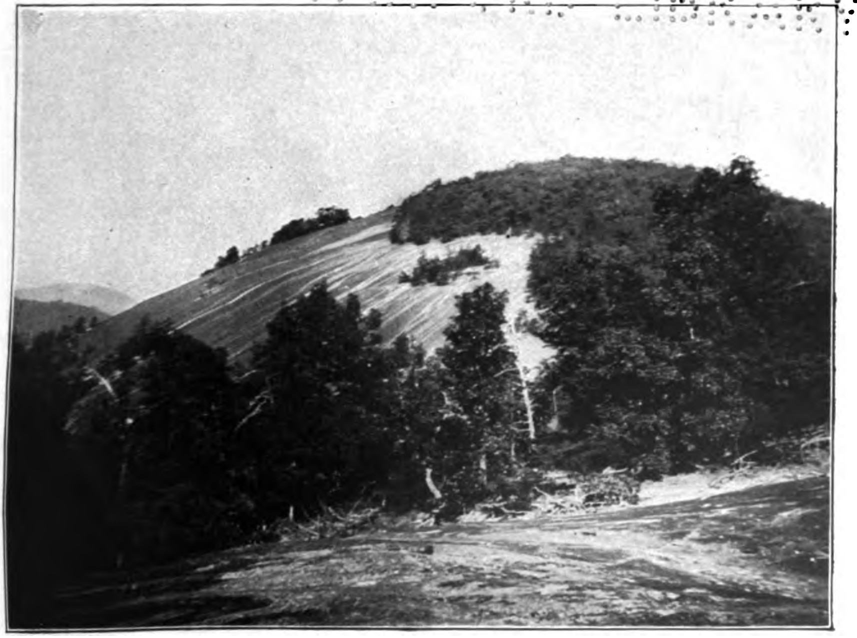


B. STONE MOUNTAIN, A GRANITE DOME, WILKES COUNTY, N. C.

appearance from kaolinization, and entirely fresh hand specimens of the rock could not be obtained. Two sets of joints, which strike N. 20° E. and N. 70° W., break the granite into blocks of different sizes. The N. 70° W. set is especially well developed and cuts the granite at closer intervals than the other set.

Woodleaf area.—In the northwest corner of Rowan County numerous outcrops of a biotite granite occur in and around Woodleaf station, 11 miles northwest of Salisbury. A little of the granite has been quarried from a number of small openings for local use.

The rock is a biotite granite of medium-gray color and fine grain. The feldspathic constituent includes orthoclase and microcline, the former predominating.

The vertical joints strike N. 20° E. and N. 60° E. Abundant pyrite crystals are developed on the surfaces of the joints. There are some small dark knots. A slight schistose structure is developed in places.

IREDELL COUNTY.

The Mooresville granite area, located in the southern part of Iredell County, furnishes probably the most desirable granite for monument stock in the State. A number of quarries have been worked near the town of Mooresville, from which the area derives its name.

Both even-granular and porphyritic granites occur. From the field evidence it appears that these are not simply textural phases of the same rock, but that the even-granular granite is the younger of the two and is intrusive into the porphyritic granite. Both are biotite granites and differ from each other chiefly in texture.

The *McNeely quarry,* 1 mile northwest of Mooresville, comprises several small openings made in flat bowlder outcrops, worked to a depth of less than 10 feet. The granite bears a striking resemblance to the dark blue-gray granite at Oglesby, Elbert County, Ga. (pp. 218–223).

The rock is a biotite granite of dark blue-gray color and fine grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory titanite, apatite, and zircon and secondary chlorite and epidote. Abundant feldspar and quartz intergrowths occur. Biotite manifests a tendency to segregate in minute blotches containing several shreds to the area, similar to that of the granite at Oglesby, Ga.

A few knife-edge veins of feldspar were noted in places. Only one visible set of vertical joints intersect the granite in the openings, striking N. 65° W. The granite is of good quality and is susceptible of a high polish.

The *Breed quarry,* 2 miles southwest of Mooresville, includes two openings that have been worked at intervals since 1886. The larger opening, about 200 feet in length, is in a ledge outcrop along a small stream at the base of a moderate hill slope, the top of which rises probably 20 to 25 feet higher. Stripping to a depth of 8 to 10 feet is necessary in places.

The rock is a biotite granite of dark blue-gray color and fine grain. In hand specimens it can not be distinguished from that of the McNeely quarry, to which it is similar in mineral composition. A partial chemical analysis of the granite from the west (Johnson) opening is given on page 117.

Vertical joints strike east-west, north-south and N. 45° W., the last set being less prominent than the first two. About midway of the opening a zone of close jointing about 30 feet wide is exposed, from which dimension stone can not be quarried. With this exception the joints are usually spaced 18 to 20 feet apart. Horizontal joints divide the granite into sheets 3 to 8 feet thick. Beautiful contacts between the fresh even-granular and the porphyritic granites are exposed in the east opening.

The *Biddell quarry*, 3 miles northeast of Mooresville, comprises several small openings made in 1891. The product is reported to have been shipped to Pennsylvania for use as building stone. The largest opening is about 150 feet long and is worked to a depth of about 15 feet.

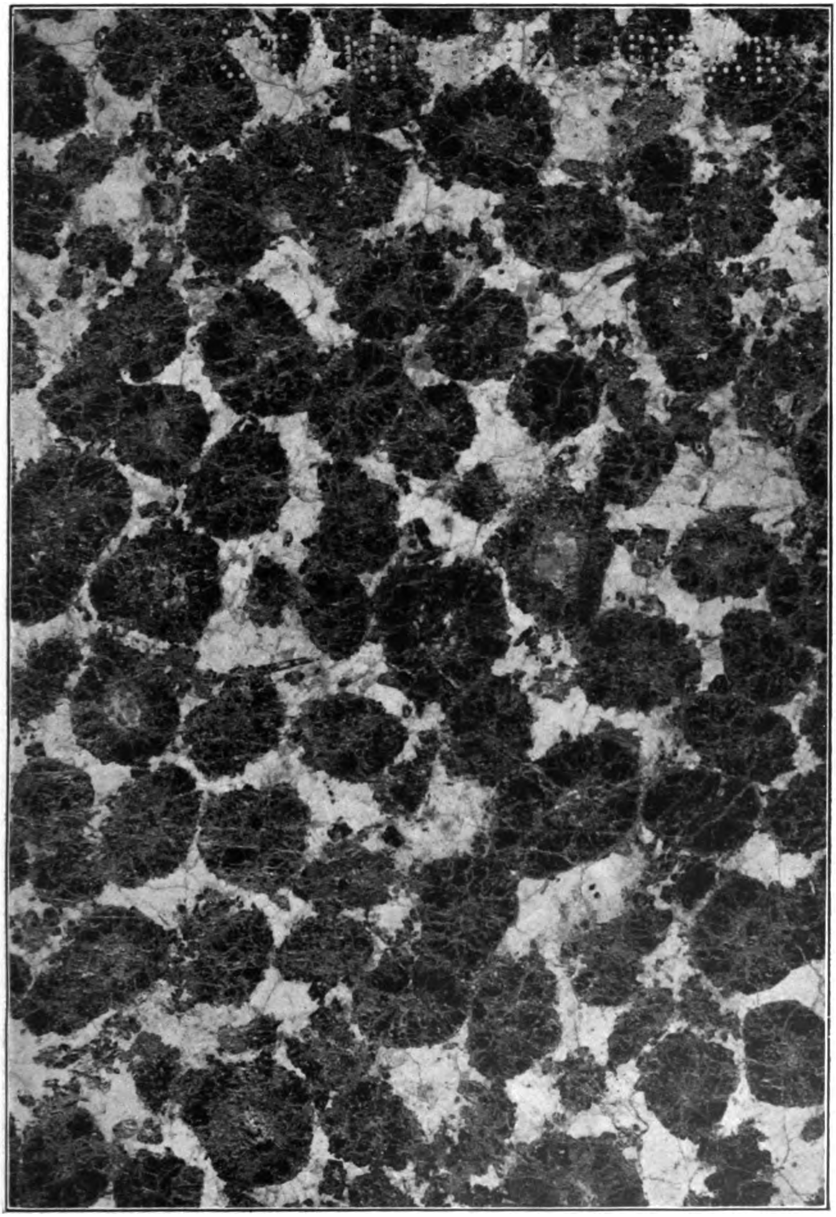
The rock is a biotite granite of medium blue-gray color and medium to fine grain. The same minerals are present as in the granite of the McNeely quarry (p. 143). Microcline is the dominant feldspar. There are a few small grains of magnetite.

Vertical joints, striking north-south and N. 65° E., are spaced at wide intervals. Pegmatite dikes, varying in thickness from 1 inch to more than 12 inches, cut the granite indiscriminately. These are so numerous that hardly a block of the granite of any size can be quarried that would be entirely free from them. Light and dark wavy streaks or bands, suggesting flowage, appear in places. Because of this irregularity and the abundance of pegmatite dikes the granite is more restricted in its use than that from the McNeely and the Breed quarries.

DAVIDSON COUNTY.

Granites occupy extensive areas over much of Davidson County. They are biotite granites of gray color, ranging from even granular to porphyritic in texture and from massive to schistose in structure. The two textures represent different facies of the same granite mass, as the porphyritic granite grades into the even-granular rock of the same mineral composition.

The granites have not been regularly worked, but some stone has been quarried from time to time at a number of places as needed to supply the local demand. The openings are all small and are located in the vicinity of Lexington, the county seat, where the rock has been



SURFACE OF ORBICULAR GABBRO-DIORITE, DAVIE COUNTY, N. C.

principally used. The earliest quarrying was done in 1856, when stone was taken out on the Conrad and Fritts places, 1¼ miles north of Lexington, for use in the court-house at Lexington. The minerals are potash feldspar (orthoclase), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory apatite, zircon, and magnetite and secondary chlorite, a colorless mica, epidote, and rutile.

A fine-grained biotite granite of schistose structure has been quarried to a small extent 2 miles south of Lexington, on the Sink place. The opening is about 100 feet long by 36 feet wide and 25 to 40 feet deep.

DAVIE COUNTY.

The principal granite areas of Davie County are limited to the eastern half of the county and represent the westward extension of the Davidson County granite area. Both even-granular and porphyritic granites of the biotite variety are known. No quarries of granite have been worked in Davie County.

On the Hairston place, 10 miles west of Lexington, there are exposures of orbicular gabbro-diorite.[a] The rock is of dark color with a greenish cast imparted by the hornblende and diallage. It presents a pronounced mottled appearance, being made up of dark-green areas of hornblende, varying from an eighth of an inch to several inches in diameter, set close together, with the interstices filled with white feldspar. (See Pl. XVIII.) On a polished surface of the stone the effect is unique and beautiful, and the rock should prove of value for ornamental and decorative purposes.

FORSYTH COUNTY.

The Winston granite area, extending over the south-central portion of Forsyth County, is the most important area in the county. Even-granular and porphyritic biotite granites are represented. These grade one into the other, representing different facies of the same mass of similar mineral composition. No quarries have been regularly worked, but several small openings have been made a few miles to the east and south of Winston to supply a local demand for stone in Winston-Salem. Quarrying has been limited to the porphyritic granite, which is described on page 169.

GUILFORD COUNTY.

Of the granite distributed in numerous areas over the northern, central, and western portions of Guilford County, but little is specially desirable for the higher grades of work. Regular quarries have nowhere been worked, but numerous small openings have been made to obtain stone of a certain grade for local use. Some stone has been quarried in five localities—the Brown Summit area, the Summerfield area, the Friendship area, the Jamestown area, and the Greensboro area.

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[a] Watson, T. L., Orbicular gabbro-diorite from Davie County, N. C.: Jour. Geology, vol. 12, 1904, pp. 294-303.

The granites are biotite granites, and with the sole exception of a porphyritic granite occurring near Friendship, they are even granular in texture and more or less schistose in structure.

Brown Summit area.—The Brown Summit area is located near the Southern Railway, 10 miles north of Greensboro. On the Walker place is a single opening in a light-gray foliated granite, from which a little stone was first quarried prior to the civil war.

The rock is a biotite granite, containing much muscovite in places, and of variable texture and color. Potash feldspars (microcline and orthoclase) and quartz are the principal minerals; soda-lime feldspar (oligoclase) occurs but sparingly. The effects of pressure metamorphism are pronounced in the thin sections.

Abundant pegmatite dikes, most of which strike N. 60° E., penetrate the granite. Some of them intersect, with a displacement of several inches. The principal set of vertical joints strikes N. 60° E. and the surfaces of the joints are slickensided. This granite can be used only in the lower grades of work.

Summerfield area.—Another area is located 12 miles northwest of Greensboro, at Summerfield station. Several openings have been made to obtain granite for macadamizing roads and for street work in Greensboro. The principal openings are on the Hoskins and Gamble places, within a mile of Summerfield.

The rock is a biotite granite of variable color, texture, and structure. At the Gamble opening the porphyritic texture predominates over the even granular. Soda-lime feldspar (plagioclase) is but sparingly present in the thin sections of the granite from both places. At the Gamble place dark knots occur in the granite. Vertical joints at the Hoskins opening strike N. 10° E. and N. 70° E.

Friendship area.—This area lies 10 miles west of Greensboro, near Friendship station. The only stone quarried has been the porphyritic granite described on page 169.

Jamestown area.—Half a mile southeast of Jamestown, on Bull Run, several small openings are made in a porphyritic granite. The rock is dark gray, fine grained, and thinly schistose. It is composed of a very fine-grained groundmass of quartz and feldspar with some biotite, largely altered to chlorite, much epidote, and a colorless mica, in which are embedded porphyritic crystals of oligoclase, orthoclase, and quartz. Bluish opalescent quartzes characterize the hand specimens of the rock. Vertical joints, striking N. 20° E. and N. 40° W., cut the granite porphyry at close intervals. A single diabase dike, striking N. 40° to 50° W., penetrates the granite porphyry several hundred feet north of the opening.

At the Oakdale cotton mills, on Deep River, 1 mile southeast of Jamestown, are extensive exposures of granite, which was quarried for use in building the cotton-mill dam at that point. It is a biotite granite of gray color and medium grain, somewhat schistose in structure. Soda-lime feldspar (oligoclase) nearly equals in amount the potash feldspar (orthoclase). Very little microcline is present. Dark knots, principally of segregated biotite, of irregular outline and variable size, are abundant in the granite. A number of parallel dikes of diabase, striking N. 20° E., intersect the granite at the mill site.

Some granite has been quarried on the Modlin place, 1½ miles southeast of Jamestown. It is a biotite granite of dark-gray color and medium grain. Its uniformity of color and texture make it a desirable stone for many purposes. Orthoclase and oligoclase are nearly equal in amount. Microcline was not observed in the thin sections.

Greensboro area.—Two quarries, one in granite the other in diorite, are worked for macadam just beyond the northern limits of Greensboro. The granite is a biotite granite of medium-gray color and medium-coarse grain. Nearly equal plagioclase and orthoclase, with a little microcline, quartz, and biotite, make up the essential minerals in the thin sections.

Vertical joints, spaced at close intervals, strike N. 20° E., N. 50° E., and N. 20° W. Slickensides are well developed along the joint surfaces. The granite is further penetrated by dikes of dark greenish-black amphibolite, varying from a few inches to 18 inches in thickness and striking N. 20° E. The granite is very uniform in color and texture, but dimension stone can not be quarried because of the close jointing.

ALAMANCE COUNTY.

Granites of irregular color and texture are found in the vicinity of Burlington, the county seat of Alamance County, principally to the north, east, and southeast of the town. They are biotite bearing, schistose in places, and of little value except for the lower grades of work. According to the amount of biotite present the color varies from very light to medium and dark gray. In texture the rock ranges from fine to moderately coarse.

A number of small openings have been made in places to obtain stone for purely local purposes. About 4 miles north of Burlington small quantities of the granite have been quarried for window and door sills in factories of that vicinity. Two miles east of Burlington granite of variable color, texture, and structure has been quarried for use as macadam. Near the southeast limits of Burlington a small quantity of granite has been quarried, but the rock at this point lacks uniformity in color and texture.

An area of syenite porphyry is exposed along Haw River and its tributaries, at the Altamahaw and Ossipee cotton mills, about 7 miles northeast of Burlington. The rock is a compact, exceedingly hard, fine-grained, dark-gray syenite porphyry. The feldspar phenocrysts are not large nor conspicuously developed in the rock. Named in order of abundance the minerals of the groundmass are orthoclase, oligoclase, biotite, muscovite, epidote, magnetite, pyrite, and a little quartz. Oligoclase, some orthoclase, and less biotite are the porphyritically developed minerals.

Vertical joints strike N. 10° E. and N. 60° to 70° W. A few pegmatite dikes occur. Several small openings have been made and a little of the stone has been quarried for use as granite.

WESTERN PIEDMONT GNEISS AND GRANITE BELT.

INTRODUCTORY STATEMENT.

The rocks of the western Piedmont in North Carolina are composed largely of schists and gneisses of the mica type. They show considerable variation in composition and texture where examined, and are probably in large part of sedimentary origin. Some of the gneisses, however, are certainly altered igneous masses whose structural resemblances to sedimentary rocks are due to the effects of dynamometamorphism.

Besides these there are areas of both acidic and basic igneous rocks invading the gneiss-schist complex. Among the acidic igneous rocks are massive and foliated granites that are workable in many parts of the belt, the more important areas being in Surry, Wilkes, Alleghany, and Alexander counties. There are other granite areas in this belt, but so far as known they are of little economic importance.

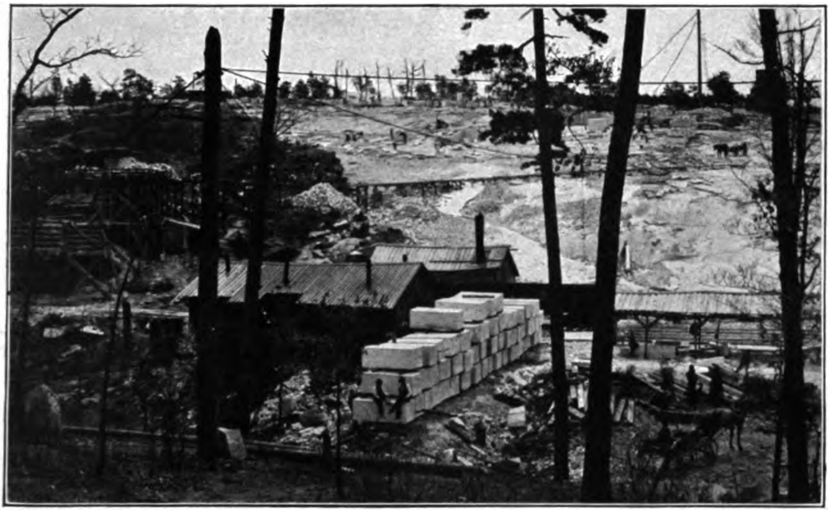
At present granite quarrying in the belt is limited exclusively to Surry County, where, in the vicinity of Mount Airy, one of the largest quarrying industries in the State is developed.

GRANITE.

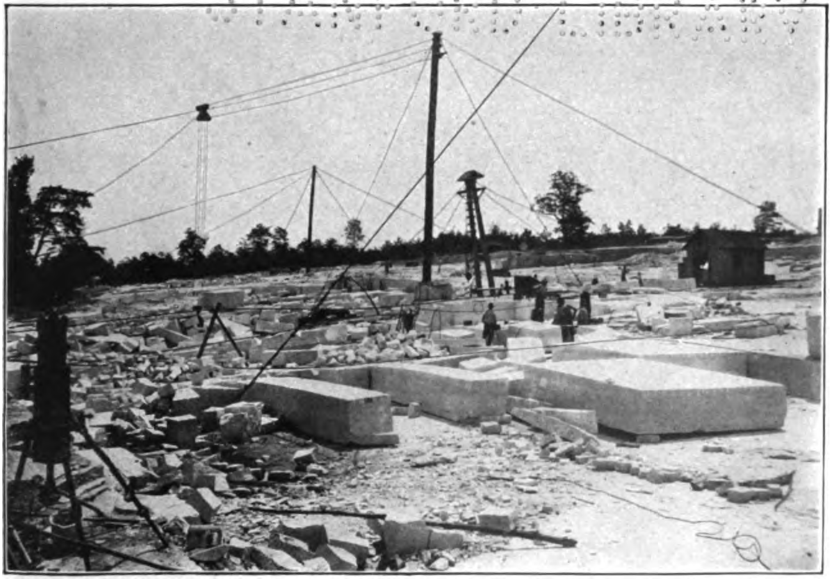
Surry County.—The principal outcrops of granite in Surry County are found in the northern part of the county near the Virginia line, in the vicinity of Mount Airy, the county seat. The granite is exposed in flat-surfaced masses in rather an advanced stage of decay, immediately to the north and south of Mount Airy, where quarrying on an extensive scale has been conducted for some years.

The *North Carolina Granite Corporation's* (*Mount Airy*) *quarries*, located less than 1 mile northeast of Mount Airy, were opened in 1889 and the first shipment of stone from them was made in July, 1890. The total shipment of granite from these quarries from 1890, when 135 carloads were shipped, to 1904, when 1,282 carloads were shipped, was 13,232 carloads. (See Pl. XIX, *A*, *B*.)

Quarrying is confined to a 40-acre tract of continuously exposed granite over the slope and top of a long hill, which rises about 125 feet



A.



B.

MOUNT AIRY GRANITE CORPORATION'S QUARRIES, SURRY COUNTY, N. C.

above the valley bottom. The company holds more than 200 acres additional of ground over which granite is exposed. Quarrying has extended over practically the entire 40-acre tract, the greatest depth of working being about 30 feet.

The rock is a biotite granite of very light gray, nearly white color and medium grain. The biotite is not, except in one opening, equally distributed through the granite, but is entirely absent from some parts of it, is uniformly distributed through others, and shows a marked tendency to segregation in still other parts. Quartz-feldspar areas of extreme whiteness, ranging from several inches to as many feet in diameter, in which biotite is entirely lacking or represented by only a few shreds, are common through the granite. This unequal distribution of the characterizing accessory (biotite) renders the granite in places less uniform in color than might be desirable for some purposes. The granite that has a uniform color is most pleasing in appearance and forms excellent and desirable stone for all uses except for monumental stock, for which the contrast of color between the cut and polished faces is not great enough.

Microscopically the principal minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory apatite and zircon, and secondary chlorite, epidote, light-colored mica, and iron oxide. Plagioclase feldspar exceeds the potash feldspars in amount. Zonary structure and Carlsbad twinning are beautifully developed in some of the feldspars. Intergrowths of the feldspars with one another and with quartz are abundant. A partial chemical analysis of the granite is given on page 117.

The crushing strength of the granite is well shown in the following tests, made on specimens of the stone by different parties and at different places:[a]

Crushing strength of 2-inch cubes of granite from quarries at Mount Airy, N. C.

Marks.	1.		2.	
	Crushed at—	Strain per square inch.	Crushed at—	Strain per square inch.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
M. A. 1	80,725	20,488	79,900	19,750
M. A. 4	86,450	21,292	80,350	20,088
M. A. 7	90,780	22,469	81,600	20,400
M. A. 10	84,410	20,686	....	....
M. A. 13	80,000	19,703	....	....
M. A. 16	74,870	18,384	....	....
Mean	....	20,497	....	20,076

1. U. S. Navy-Yard, Washington, D. C., April 16, 1896; Charles O'Neil, commander, U. S. N., and Bureau of Ordnance, U. S. N.

2. Testing department of the Philadelphia Scale and Testing Machine Works, Philadelphia, Pa., November 4, 1895; Riehle Bros.

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[a] Bull. North Carolina Geol. Survey, No. 2, 1906, pp. 155-156.

The specimens broke suddenly with a loud report, several large pieces and a lot of fine material resulting from each test.

Two tests made by Prof. F. P. Venable, of the University of North Carolina, at Chapel Hill, October 24, 1895, as to the capacity of the granite from Mount Airy for absorbing water, yielded the following result:

Weight, in grams, of water absorbed by granite from Mount Airy, N. C.

	1.	2.
Weight when dried	830.4	1,001.7
Weight after being soaked in water 24 hours and then allowed to dry in air 24 hours	830.8	1,002.1
Weight of water absorbed in 24 hours	.4	.4

The veins and dikes found in most granites are not seen in the Mount Airy quarries, and visible vertical jointing is almost entirely lacking.

The company is adequately equipped with all necessary modern machinery and appliances for quarrying and handling the stone. In 1905 a large stone-cutting plant was erected. The stone is carried from the quarries to the railway cars by a system of inclined cableways, run by gravity. The limit in size of dimension stone is the capacity of the railroad cars. Blocks weighing 20 tons are reported to have been frequently shipped from the quarries. (See Pl. XX.)

The product is marketed over a large territory, chiefly in the States south of New York. It is used for general building and paving purposes. The quarry waste is utilized for concreting, roofs on cotton mills, macadam on streets and roads, ballast along the railroads, and granolithic work. All the stone used in the large dry dock at Newport News, Va., and the concreting material used in the Fort Caswell fortifications, Cape Fear River, North Carolina, came from the Mount Airy quarries.

The method of quarrying the granite[a] consists in drilling a hole about 3 inches in diameter perpendicular to the surface to a depth equal to the thickness of the stone desired, usually 5 to 7 feet, and then firing a succession of light blasts. The operation is begun by discharging about one-fourth of a pound of dynamite in the bottom of the hole; this small charge pulverizes the stone slightly and forms a small chamber. The tamping is then cleaned out and the hole is recharged in the same manner, this time, however, with about a handful of powder. Small charges of powder are exploded in the hole until a small seam has been started at the bottom, extending parallel with the surface. To determine if this has been done, a small steel rod bent at the lower end and sharpened to a point is

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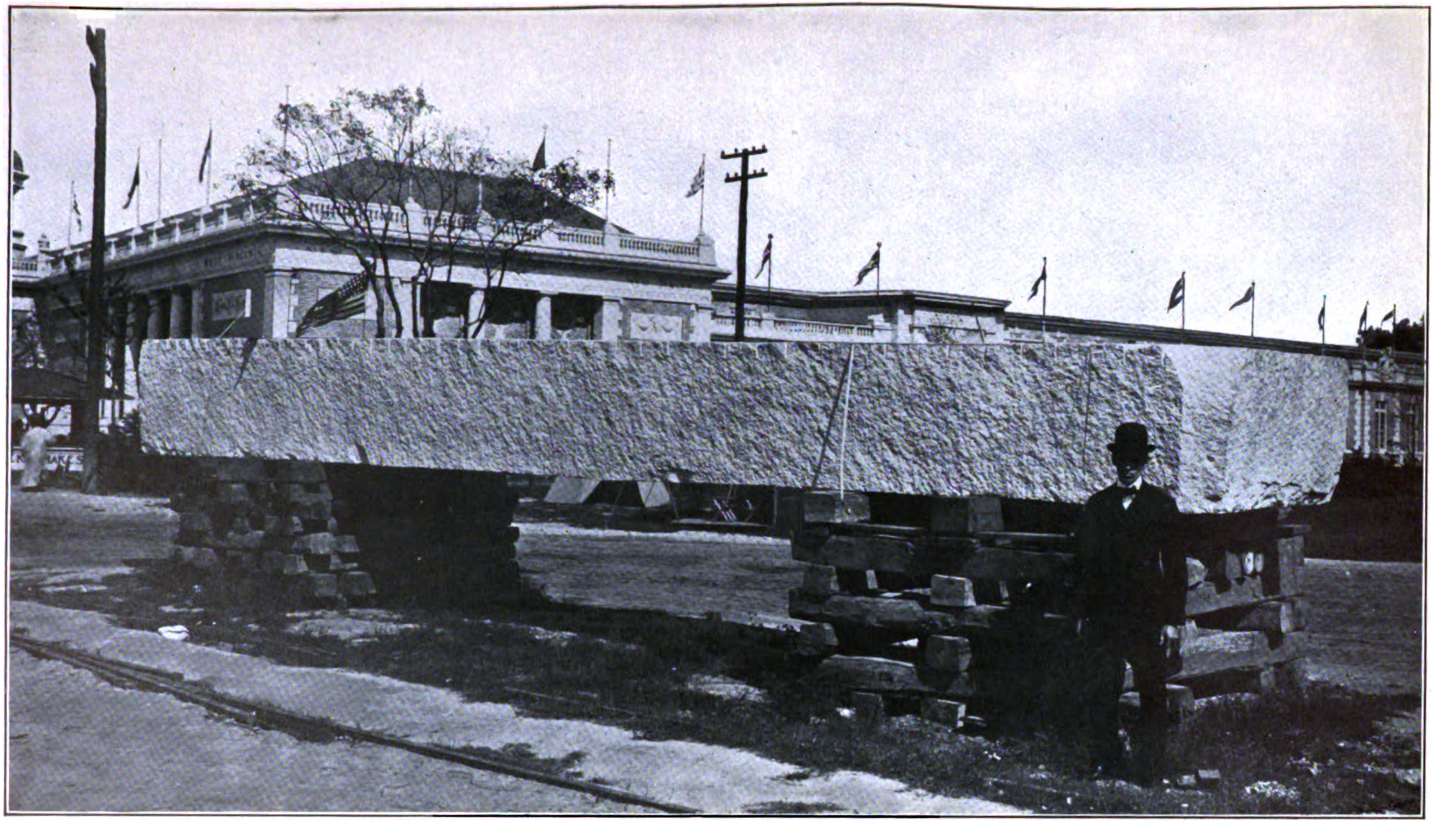
[a] Bull. North Carolina Geol. Survey, No. 2, 1906, pp. 157-160.



GRANITE MONOLITH FROM MOUNT AIRY, SURRY COUNTY, N. C.

passed up and down the hole until the crack is located. After the crack has once been started the charges are gradually increased until it extends a distance of 75 feet or more from the hole. The use of explosives is then discontinued, and a water-tight connection to the hole is made by fastening a piece of iron pipe in the hole with melted sulphur. To this connection is attached an ordinary hand force pump, and water is pumped into the crevice formed by the explosives. The crevice is extended by continuous pumping for a few hours until finally it covers an area of perhaps 2 acres and the pressure finds vent by tearing the rock out to thin edges on the side of the hill. This method is used in the warmest weather, when the surface of the rock is naturally somewhat expanded and more easily raised. It is very doubtful whether it could be employed during cold weather; experience shows that the hotter the weather the easier the work. Sheets of stone covering areas of 1 to 2 acres and from 6 to 8 feet thick close to the hole are easily raised by this method. It is found necessary to clean off a ledge of stone made in this manner before attempting to form or raise another sheet on the surface below. For this reason the quarry covers considerably more area than one having natural seams—horizontal sheeting.

In another method now used the sheets are split off with compressed air, which has been found to be even more effective than water. The method of employing compressed air, according to Mr. Thomas Woodroffe, vice-president of the company, is as follows:

The procedure is the same as that just described, until the crevice extends a distance of 75 feet or more from the hole in all directions. A pipe is then cemented into the hole and connected by means of a globe valve to an air pipe line from an air compressor. Compressed air at a pressure of 70 to 80 pounds is gradually admitted and the crack is rapidly extended until it comes out on the hillside. A sheet several acres in extent may be raised in this manner, affording a bed plane approximately horizontal, to which the quarrymen can work, thus obtaining stone of any required thickness. The first time this method was used, air under a pressure of 80 pounds was admitted into the cavity which had previously been extended to a distance of 100 feet from the lift hole. The power of the air, however, was too great for the easily splitting stone and the cleavage turned abruptly to the surface. In the next hole, however, the compressed air was admitted very gradually and the stone could soon be heard cracking in all directions, and in about half an hour the cleavage came to the surface of the hillside about 225 feet from the lift hole. To extend the cleavage by means of powder for 100 feet would require from six to twelve days and with water from three to five hours, whereas with compressed air a larger area was split in half an hour.

Wilkes and Alleghany counties.—Lying partly in the northeastern portion of Wilkes County and partly in the adjacent southeastern portion of Alleghany County are numerous closely grouped large granite bosses or dome-shaped residual masses. One of the largest of these is Stone Mountain (see Pl. XVII, *B*), 20 miles slightly east of north of Wilkesboro, the county seat of Wilkes County. Some of the other large masses are Little Stone Mountain, Cedar Rock, Wolf Rock, and Beauty Falls Rock.

These granite masses vary in height from 100 to 600 feet and in circumference at the base from 2 to 6 miles. There are eight or ten of them, characterized by steep, nearly precipitous slopes rising from narrow intervening valleys. Both the tops and the slopes are usually covered with a scant veneer of soil, sufficient in many places to maintain a fair growth of trees. In some of them, however, the tops and the slopes are entirely bare, exposing the hard though partly decayed granite.

These residual masses are composed of granite of similar color, texture, and composition. It is a biotite granite of light-gray, nearly white color and medium grain, a trifle coarser grained than the granite from the Mount Airy quarries, which it otherwise closely resembles. Fresh specimens of the granite could not be obtained, as no quarries have been opened. Dark areas (knots) chiefly of segregated biotite, are somewhat abundant in certain portions of the granite. Like the granite of the Mount Airy quarries, the rock of these bosses is largely free from vertical joints. Less than half a dozen joint planes were observed in the Stone Mountain mass; their strike was northeast and northwest. In the narrow valleys separating the large masses the granite is broken by two principal sets of closely spaced vertical joints, which have general northeast and northwest strikes.

GNEISS.

The western Piedmont belt is composed largely of gneisses of variable composition and texture, which in many places could be quarried and used to advantage in certain grades of work. One of the most promising bodies of gneiss, commercially, in this belt is Rocky Face Mountain, in Alexander County, about 6 miles northeast of Taylorsville, the county seat. This mountain is an elliptical dome-shaped mass of granite gneiss rising to an elevation of not less than 500 feet above the surrounding plain and measuring several miles around the base. It has an approximate northeast-southwest trend and generally steep slopes.

The rock is a biotite granite gneiss of light-gray color and medium grain. The banding is of irregular thickness though generally thin.

The principal minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with the usual accessories. Feldspar intergrowths (microperthite) are abundant. Red garnet in small grains and crystals is a common mineral in places. Recrystallization and crushing of the rock minerals are pronounced in the thin sections.

Vertical joints, spaced at wide intervals and of inconspicuous development, strike N. 30° E. and N. 80° E. A few quartz veins, contorted and crushed from pressure metamorphism, penetrate the rock in places.

No quarries have been opened, but stone has been stripped from the surface in several places for local use. The rock is closely similar to the contorted biotite granite gneiss at Lithonia, DeKalb County, Ga., and at Beverly, Pickens County, S. C., described on pages 197–198, 253–262, and should prove equally desirable.

APPALACHIAN MOUNTAIN GRANITES.

GENERAL DESCRIPTION.

In North Carolina the Appalachian Mountains include an irregular mountainous region lying between the steep southeastern slope of the Blue Ridge and the northwestern slope of the Great Smoky Mountains. The region has an approximate area of 6,000 square miles and an average elevation over all parts of its surface of 2,700 feet. Many of the peaks rise to elevations of more than 5,000 feet, and Mount Mitchell, the highest one, has an elevation of 6,711 feet.[a]

The principal rocks are gneisses, granites, schists, slates, limestones, quartzites, and conglomerates, cut in places by basic eruptive rocks.

Five of the geologic folios[b] published by the United States Geological Survey cover a considerable part of the North Carolina mountain province and show that it contains extensive areas of gneiss and granite suitable for building stone. With only one exception—the Whiteside granite, in the southeastern portion of the Pisgah quadrangle, covering parts of North and South Carolina—the granites and gneisses of this region are assigned by Keith to the Archean. The granite and gneiss formations in the five quadrangles, with their general character and age, are tabulated below.

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[a] Bull. North Carolina Geol. Survey, No. 2, 1906, p. 164.

[b] Cranberry (No. 90), 1903; Asheville (No. 116), 1904; Mount Mitchell (No. 124), 1906; Nantahala (No. 143), and Pisgah (No. 147), 1907.

Granite and gneiss formations of Appalachian Mountains in North Carolina.

CRANBERRY QUADRANGLE.

Archean:

Beech granite	Coarse, light-reddish porphyritic granite.
Blowing Rock gneiss	Chiefly dark coarse porphyritic gneiss.
Cranberry granite	Mainly granite and granite gneiss.
Roan gneiss	Chiefly hornblende gneiss and diorite.
Carolina gneiss	Chiefly mica gneiss and mica schist; includes other gneisses, granite, and diorite.

ASHEVILLE QUADRANGLE.

Archean:

Max Patch granite	Coarse or porphyritic, light gray or red.
Cranberry granite	Mainly granite and granite gneiss.
Roan gneiss	Chiefly hornblende gneiss and diorite
Carolina gneiss	Chiefly mica gneiss and mica schist; includes other gneisses, granites, and diorites and small lenses of marble.

MOUNT MITCHELL QUADRANGLE.

Archean:

Henderson granite	Porphyritic granite and gneissoid granite.
Cranberry granite	Mainly granite and granite gneiss.
Roan gneiss	Chiefly hornblende gneiss and diorite.
Carolina gneiss	Chiefly mica gneiss and mica schist; includes other gneisses, schists, granite, diorite, and small lenses of marble.

NANTAHALA QUADRANGLE.

Archean:

Granite	Granite and gneissoid granite.
Roan gneiss	Hornblende gneiss, hornblende schist, and diorite.
Carolina gneiss	Mica gneiss and mica schist.

PISGAH QUADRANGLE.

Post-Cambrian:	
Whiteside granite	Biotite-muscovite granite, slightly schistose.
Archean:	
Henderson granite	Porphyritic granite and gneissoid granite.
Roan gneiss	Chiefly hornblende gneiss and schist.
Carolina gneiss	Chiefly mica gneiss and mica schist; includes other gneisses, granite, and diorite.

The principal characters of these formations, beginning with the oldest, as mapped and described by Keith, are briefly summarized below.

CAROLINA GNEISS.

The Carolina gneiss, so named because of its great extent in North and South Carolina, is the oldest formation in the region. It is the most extensive formation in the mountain region and consists of an immense series of interbedded mica gneiss, mica schist, and fine granitoid layers of light or dark gray color. In places granite masses up to 100 feet thick cut through the gneiss at all angles. These are massive, fine grained, uniform in texture, and of light-gray color, and are composed of quartz, orthoclase, and plagioclase feldspar, biotite, and muscovite, the last usually in subordinate amount. The mica schists are rarely coarse grained, and are composed of quartz, muscovite, a little biotite, and a very little feldspar. The granitoid layers contain quartz and feldspar, with muscovite and biotite in small amounts; in the light-colored bands the biotite and most of the muscovite are lacking. The granitoid layers and schists alternate in bands varying from a few inches up to 50 feet in thickness. Bands similar in composition and from one-tenth of an inch to 1 inch thick form the banded gneisses.

As a rule, the Carolina gneiss is too irregular in texture and structure to be of value as a building stone. Many of its bands can be used for rough work, such as retaining walls, foundations, macadam, and ballast. The granite and gneiss bands in the Carolina gneiss are quarried in the vicinity of Asheville and are used chiefly for road material. The roads in the vicinity, and especially those of Asheville, are constructed of rock from this formation and are reported to be very satisfactory.

ROAN GNEISS.

The Roan gneiss, so named from Roan Mountain, on the boundary of North Carolina and Tennessee, consists chiefly of hornblende gneiss, hornblende schist, and diorite, with some interbedded mica schist and gneiss similar to the Carolina gneiss. It is younger and very much less extensive than the Carolina gneiss, and as yet has proved of no value as a building stone.

CRANBERRY GRANITE.

The Cranberry granite, named from Cranberry, Watauga County, N. C., consists of granite of varying texture and color and of schists and granite gneisses derived from granite. A broad belt of this granite passes diagonally through the Asheville quadrangle, extending southwestward through the Mount Guyot quadrangle and northeastward through North Carolina and far into Virginia. Its principal minerals are quartz, orthoclase and plagioclase feldspar, biotite, muscovite, and in places hornblende. Minor accessory minerals are magnetite, pyrite, ilmenite, garnet, and epidote. Feldspar greatly predominates, imparting a light-gray color to the granite, as a rule.

The granite varies from light gray, nearly white, to red in color and from a fine, even-grained rock to a coarse-grained porphyritic granite in texture and is schistose in structure. The Cranberry granite is one of the most desirable in the mountain region of the State for building stone, and its areas afford abundant opportunity for the location of quarries.

Southeast of Hayesville, Clay County, in the Nantahala quadrangle, is a belt of biotite granite which Keith states is probably to be correlated with the Cranberry granite. It is of fine or medium grain, mostly massive but partly gneissoid and schistose in structure, and composed chiefly of orthoclase and plagioclase feldspar, quartz, biotite, and muscovite, named in the order of abundance. Minor accessory minerals are hornblende, pyrite, magnetite, and garnet. This granite is probably too variable in texture and color and in places too schistose to yield desirable building stone.

BLOWING ROCK GNEISS.

The Blowing Rock gneiss derives its name from a large body of gneiss exhibited in Watauga County, near Blowing Rock. It extends southward into Caldwell County. "The formation consists entirely of gneiss of two varieties, one with large, porphyritic crystals, the other of very fine, even grain. The former consists of large orthoclase crystals embedded in a groundmass of feldspar, quartz, biotite, and muscovite; the latter consists of the same minerals in crystals of uniform size and granitoid appearance."[a] The feldspar phenocrysts are commonly twinned and range in length up to 3 inches. Owing to the large amount of biotite present, the gneiss is of dark-gray or blackish-gray color. In some places the porphyritic and even-grained gneisses grade into each other; in others they are interbedded. Because of its schistose structure the Blowing Rock gneiss yields easily worked slabs, which split readily along the planes of foliation. Keith mentions this rock as an ornamental stone.

BEECH GRANITE.

A large area of the Beech granite occupies the southwestern portion of Watauga County in Beech Mountain, from which it derives its name, and extends westward into Tennessee. It is a coarse-grained porphyritic granite composed of orthoclase and plagioclase feldspar, quartz, biotite, and very little muscovite. Orthoclase is the porphyritic mineral, the phenocrysts measuring 2 inches in length. Feldspar is largest in amount and usually imparts a light color to the rock. Biotite is abundant in the more massive portions of the rock, giving a spotted appearance to the granite because of the large size of its crystals. Near the border of the area a coarse red granite occurs, the red color being due to the pink or red feldspar present in the rock. This granite has been squeezed and mashed until it has acquired a pronounced gneissoid structure.

MAX PATCH GRANITE.

The Max Patch granite is displayed in ten or more areas in Madison and Haywood counties, N. C., chiefly the former, and extends into Cocke and Unicoi counties, Tenn. The largest area surrounds Max

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[a] Pisgah folio (No. 147), Geol. Atlas U. S., U. S. Geol. Survey, 1907, p. 3.

Patch Mountain, from which the formation derives its name, near the Tennessee–North Carolina boundary, in the extreme southwest corner of Madison County. Keith describes the Max Patch granite as follows:[a]

> The formation consists almost entirely of coarse granite, in places porphyritic and in places of uniform grain. The minerals which compose the rock are orthoclase and plagioclase feldspar, quartz, biotite, and a very little muscovite. Accessory minerals are magnetite, pyrite, and epidote, the latter being, for the most part, in secondary veins and patches. Porphyritic crystals of orthoclase feldspar whose lengths exceed 1 inch are not infrequently to be seen. These are most common north of Big Laurel Creek, where the formations cross the state boundary into Tennessee. The other masses, particularly that around Bluff Mountain, are composed of the uniform massive variety, which is more characteristic of the formation as a whole. In the porphyritic varieties the feldspars make by far the greatest part of the rock, giving it a light-gray or dull-whitish color. In the massive parts of the formation biotite is prominent and causes a decidedly spotted appearance by the large size of its crystals.
>
> Another variety of great extent is a coarse red granite. This appears to be a modification of the usual massive rock, from which it differs only in having many red or pink feldspars. These give a very marked red color to the whole rock.

The feldspar is in places partly altered into epidote and saussurite. In the extreme stage of alteration the feldspar has been so far replaced by the epidote that this mineral composes one-third or one-half of the bulk of the rock. This is especially noticeable on Max Patch Mountain, but it is by no means restricted to that locality. Practically all the feldspars have been so altered in other places. Likewise the biotite is altered into chlorite and fibrous hornblende. Besides these processes there was a considerable growth of epidote in small veins and segregated patches, described under unakite below.

Like the Cranberry granite, the Max Patch granite has been squeezed and mashed until at many places it has developed a pronounced gneissoid structure. Those portions of the Max Patch granite which are marked by red feldspar and yellow-green epidote should prove desirable for ornamental stone. The porphyritic portions of the granite also present a striking appearance and might be used to advantage for the same purpose. Opportunities for quarrying are abundant, especially along the streams, where fresh rock can be readily obtained.

UNAKITE.

A type of granite occurring in this area is the unique and beautiful variety known as unakite, composed of yellow-green epidote, dull pink or red feldspar, and quartz. It occurs in small narrow veins and segregated patches in the Max Patch granite described above. The unakite where observed is not uniform in color and composition but shows pronounced gradations into a pink feldspathic rock on the one hand and a yellow-green epidote rock on the other. The several phases of the rock here described usually occur in the same "vein," the unakite proper occupying, as a rule, the middle portion and grading toward the sides, next to the inclosing granite, into either a feldspathic or an epidote rock or both. The typical unakite portions of the "veins" show a coarse massive rock of even texture and of light-pink and green color.

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[a] Asheville folio (No. 116), Geol. Atlas U. S., U. S. Geol. Survey, 1904, p. 4.

The exposure best showing the relations between the unakite and the Max Patch granite was seen along Roaring Fork, a short distance above its entrance into Meadow Fork. At this point the vein character of the unakite was entirely apparent. The other exposures examined were almost entirely covered by decayed material which obscured the contacts between the unakite and the inclosing rock, and therefore revealed little or nothing of the real relations between the two.

Microscopically, the unakite-bearing (Max Patch) granite is composed of orthoclase and microcline in nearly equal proportions, a little plagioclase, quartz, a little biotite, zircon, apatite, rutile, magnetite, and a few small grains of pyrite. The secondary minerals are a colorless and a green mica, epidote, chlorite, and kaolin. The epidote is clearly an alteration product derived from the interaction of the ferromagnesian constituent and the feldspar. It occurs in the form of minute microscopic granules, thickly crowded together in large and small areas in the feldspar, next to the biotite where that is present. The quartz contains innumerable long lines of threadlike inclusions of rutile, broken into very many minute segments but always perfectly aligned. In addition to the epidote the colorless mica derived from the feldspar almost completely obscures, in a few places, the original mineral.

Some peripheral shattering is manifested in the small interstitial areas and the narrow border zones of a fine-grained mosaic. The effect of dynamic forces is further shown in strain shadows and lines of fracture in the quartz and feldspar. In some places the larger feldspar grains are much fractured and the lines are filled with another mineral; in others alteration has progressed along these lines and patches of deep-green mica are developed in them.

A thin section of the unakite shows a moderately coarse-grained granite composed of orthoclase, quartz, and epidote, with titaniferous iron oxide largely altered to leucoxene, rutile inclusions, and secondary muscovite. The quartz and feldspar individuals are considerably fractured, and they show additional strain shadows with some peripheral shattering, indicative of intense dynamic deformation.

The epidote shows, from its mode of occurrence and association in the thin sections, that it is entirely a secondary mineral. It occurs in large masses composed of minute microscopic granules, many of them replacing the entire feldspar individuals, and as continuous and irregular disconnected bands and areas of large and small size, following the fractures in both the feldspar and the quartz but most extensively developed in the feldspar. The development of epidote along the breakage lines can be continuously traced in many places from the larger areas or masses replacing the entire feldspar individuals across or into contiguous feldspars. In still other places the feldspar shows scattered granules of epidote over its surface. All gradations between these two extremes of epidotization appear. Hardly any of the feldspar in the sections examined was entirely free from some epidotization.

Besides epidote, the other (secondary) mineral matter consists mostly of quartz, which locally fills the cracks in the larger quartz and feldspar grains made by the fracturing. Some of the less epidotized feldspar shows additional alteration into a colorless mica and some kaolin. No plagioclase and no ferromagnesian minerals were recognized in any of the sections of the unakite.

HENDERSON GRANITE.

The Henderson granite derives its name from the extensive areas and exposures of the granite in Henderson County, N. C. It crosses the Pisgah quadrangle (Henderson and Transylvania counties) in a northeast-southwest direction, in a belt 6 or 8 miles wide, and extends southwestward into South Carolina. The granite is composed chiefly of orthoclase and plagioclase feldspar, quartz, muscovite, and biotite, named in the order of their abundance. Biotite is usually subordinate in amount but is subject to much variation. Both porphyritic and even-granular varieties of the granite are common, grading into each other. The granite is gray in color and generally gneissoid in structure, although small areas of massive rock, usually fine or medium grained and containing very little biotite, occur here and there. In the gneissoid portions of the porphyritic granite the feldspar phenocrysts are drawn out to more than twice their original length, few of the unaltered crystals being more than an inch long.

Extensive outcrops of the Henderson granite are common throughout the area, especially near French Broad River, in cliffs and steep slopes which afford available quarry sites. Keith states that the stone dresses well and is exceedingly hard and durable. Much of the granite has been quarried at the following places on or near the French Broad: At Johnson Bridge or Horseshoe, Henderson County; several miles north of Hendersonville, at Balfour station, by the Balfour Quarry Company; less than 2 miles east of the Transylvania-Henderson county line, near Etowah, in Henderson County; and at several points near Wilson Bridge in Transylvania County. The product was used locally in bridges and buildings and for railroad ballast and macadam.

WHITESIDE GRANITE.

The Whiteside granite derives its name from Whiteside Mountain, where, according to Keith, it forms a series of enormous cliffs. (See Pl. XIV, *B*.) There are 2 acres of the granite lying on the east and west sides of the Henderson County line, extending southeastward into South Carolina and southwestward into South Carolina and Georgia. It is a biotite-muscovite granite of light-gray color and fine to medium grain, and is generally massive in structure. Because of its massive character and because it cuts the other rocks of the region, Keith refers it doubtfully to post-Cambrian age and states that it may be as late as Carboniferous. Named in the order of their importance, the principal minerals are orthoclase and plagioclase feldspar, quartz, muscovite, and biotite. Minor accessory minerals are magnetite, ilmenite, pyrite, and garnet. Feldspars are the dominant minerals. Biotite varies considerably in amount and in places is entirely lacking. A porphyritic phase of the granite occurs in places along the border portions of the area.

Regarding the economic features of this granite Keith says:[a]

> The Whiteside granite yields excellent stone of a more massive texture than the Henderson. Its color is light gray or white, and its grain is medium and very uniform through large bodies. It splits out in thick sheets and dresses very well. Its durability is shown by its enormous cliffs in Table Rock and Lookingglass Mountain. Along the Blue Ridge are found the best natural outcrops, but quarries could be developed readily at nearly any locality in the areas. The cover of soil is seldom heavy over the rock and weathering is not deep. The stone has been used for dams, chimneys, and abutments.

SUMMARY OF THE GRANITES OF THE MOUNTAIN REGION.

Granites are widely distributed over many parts of the mountain region of North Carolina. As a rule, they are gneissoid in structure as a result of intense pressure metamorphism, although massive forms are by no means uncommon. In color they range from nearly white through different shades of gray to deep reddish pink, and in texture from fine or medium, even granular, to coarse porphyritic. The principal minerals are potash and plagioclase feldspars, quartz, biotite, and muscovite, with a little hornblende in places. Much epidote and chlorite are present locally as secondary minerals derived from the alteration of the feldspars and micas. With but few exceptions the granites are pre-Cambrian in age.

There are in the region extensive areas of gneiss, principally micaceous and hornblendic, having variable composition and texture. In addition to the rocks of granitic composition, volcanic rocks of both acidic and basic types, massive and schistose in structure, are found, some of which are of commercial value.

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[a] Pisgah folio (No. 147), Geol. Atlas U. S., U. S. Geol. Survey, 1907, p. 8.

Numerous extensive exposures of the granite afford desirable locations for quarries. Some of the exposures are accessible and can be quarried; other areas are at present inaccessible to lines of railway and must remain undeveloped except to supply a strictly local demand. Many small openings have been made in places to supply stone for local uses. The product has been used in buildings and bridges but mainly for ballast and macadam. Much of the granite is suitable for building and ornamental purposes. Dimension stone of uniform color and texture can be quarried and some of it is susceptible of a handsome and durable polish.

PORPHYRITIC GRANITES.

GENERAL STATEMENT.

Porphyritic granites are intimately associated in places with the even-granular granites of the Coastal Plain, Piedmont, and Mountain provinces. They are widely distributed, rather extensive areas occurring in nine of the Piedmont counties (Cabarrus, Davidson, Davie, Forsyth, Franklin, Gaston, Guilford, Iredell, and Rowan) and two in the Coastal Plain (Anson and Richmond).

Regular quarries have nowhere been opened in the porphyritic granite, but in most of the areas small openings have been made from which granite has been quarried to supply a local demand. Reasonably good exposures of the porphyritic granite occur in places, but as a rule the rock is more or less deeply decayed and is readily traced by the kaolinized feldspar phenocrysts in the residual material.

A striking similarity is shown in the different areas of granite of this type. The porphyritic granites of the Coastal Plain and Piedmont provinces are massive in structure, light to dark gray in color, and medium to coarse grained in texture. Those of the Mountain province are usually more or less foliated as a result of pressure metamorphism. The ratio of phenocrysts to groundmass is variable, almost every gradation being traceable between normal and even-granular granite, in which phenocrysts are entirely absent, to a typical porphyritic granite in which phenocrysts of feldspar predominate.

In mineral and chemical composition the porphyritic granites are identical with the even-granular granites, the only essential difference being that of texture. Gradation from one into the other could readily be traced in many of the areas, indicating that they are simply different textural facies of the same rock mass.

MICROSCOPIC CHARACTERS.

Microscopically, the porphyritic granites are biotite granites containing the same essential and accessory minerals as the even-granular granites. They are mixtures of feldspar and quartz with biotite, these minerals occurring in descending abundance in the order named.

The groundmass ranges from a medium to a coarse-grained biotite granite. Orthoclase is usually the dominant feldspar, although microcline or plagioclase may equal or in some places exceed it in amount. Intergrowths of the potash feldspar with plagioclase (microperthite), and with quartz in micrographic structure, are abundant. Micropoikilitic feldspars, chiefly from other included feldspars, are common. Quartz and biotite are the other essential minerals. Apatite, zircon, magnetite, and locally titanite occur as accessory minerals. Chlorite, epidote, and a light-colored mica are the usual secondary minerals, derived chiefly from the alteration of the biotite and feldspars.

Only the potash feldspars, orthoclase, and microcline, are porphyritically developed. They range from white and opaque through flesh-colored to pink in color; from 1 inch to 2 inches in length by one-fourth to 1 inch in width; from flat-tabular idiomorphic (with crystal faces) to irregular rounded allotriomorphic (without crystal faces) individuals in outline. Many of them are twinned on the Carlsbad law and as a rule they contain inclosures of biotite. The flat-tabular idiomorphic forms of white color usually prevail. They are generally of conspicuous development, rarely showing gradation into the groundmass feldspar, and in a number of specimens a rude tendency toward orientation is displayed. Like the phenocrysts of the Georgia porphyritic granites, described on pages 216, 238–250, those of the North Carolina areas show an origin in place rather than an intratelluric origin.

COASTAL PLAIN PORPHYRITIC GRANITES.

ANSON AND RICHMOND COUNTIES.

The Wadesboro-Rockingham area, located in the Coastal Plain region south of east from Charlotte, near the South Carolina boundary, has an east-west length of approximately 14 miles, lying partly in Richmond and partly in Anson County. For the extension of the same granite into South Carolina see pages 191–193. About 1 mile east from the western exposure of the granite the Triassic sandstones first appear, overlying unconformably the crystalline schists. The area between the granite and the sandstone is composed of crystalline schists of variable mineral composition. Irregular stretches of the Coastal Plain sands cover the granite over many of its parts. Outcrops of the fairly fresh granite are somewhat numerous, largely in the nature of huge bowlders, ledges, and flat-surfaced masses, the last containing several acres of surface in the largest exposures. Exposures of the fresh and weathered granite are seen to advantage in the cuts of the Seaboard Air Line Railway.

The granite is a coarse-textured, porphyritic biotite granite of pronounced pinkish-gray color, tinged a delicate yellowish green which is more decided in some places than in others. The rock derives its gray color from the presence of black biotite; the pink and yellow tints are imparted by the feldspars of those shades. Over most of the area the granite has a peculiar resinous luster imparted by the feldspathic constituent.

The groundmass is a medium coarse-grained dark-gray biotite granite. Biotite is less abundant in some of the exposures and the granite is correspondingly lighter in color. This is especially true of the exposures in the cut of the Seaboard Air Line Railway about 1 mile west of Lilesville. Here the mica occurs in small hexagonal plates, deep black in color and highly lustrous. The biotite is distributed through the groundmass as single individuals and aggregates occupying distinct areas. In other places the biotite occurs as shreds and plates usually crowded close together and freely distributed through the groundmass, thus imparting a darker color to the granite.

The phenocrysts are potash feldspars with good cleavage development and having a pronounced pinkish color, in places of a decided yellowish cast. Twinning on the Carlsbad law is characteristic. The phenocrysts are more or less of idiomorphic form (with crystal outline), flat-tabular, and much elongated, although irregular rounded allotriomorphic outlines are rather common among them. They range from more than an inch in length with proportionate width down to the size of the groundmass constituents, into which they grade in places. Inclusions of biotite are somewhat conspicuous in the phenocrysts. The ratio of phenocrysts to groundmass is somewhat variable, a probable average being, as nearly as could be estimated, about 1 to 3.

Under the microscope thin sections of the granite show soda-lime feldspar (oligoclase) equal to or greater in amount than the potash feldspars (orthoclase and microcline). A thin section of the granite prepared from the exposure in the Seaboard Air Line Railway cut 1 mile west of Lilesville showed absence of microcline.

The area is readily accessible, and almost any of the large outcrops offer good quarry sites, but less than half a dozen small openings have been made. The granite is susceptible of a fine polish, and that showing the deep pink and yellowish shades should prove a desirable stone for interior work.

Vertical joints are well developed; 1¼ miles north of Lilesville the granite is cut by three sets of joints striking N. 70° E., N. 20° W., and less conspicuously north-south. At the "flat rock," 2½ miles south of Wadesboro, two sets of joints are developed, striking N. 30° E. and N. 60° W. Dikes of diabase, 25 to 300 feet wide and trending northwest, penetrate the granite in several places. Black segregated areas or bunches (knots), chiefly of biotite, are abundantly developed in some of the openings. They range from roughly rounded oval areas to much-elongated ones in which the length is several times that of the width. The largest ones are from 8 to 12 inches long by 2 to 4 inches across. Pyrite is sparingly present at the opening 3 miles west of Rockingham, where Hitchcock Creek is crossed by the Seaboard Air Line Railway.

The granite is deeply decayed in many places, but it is easily traced by the partly decayed (kaolinized) broken fragments of the large feldspar phenocrysts rather thickly strewn over the surface. Favorable sections for studying the decayed granite occur in the railroad cuts 1 mile east and 2 miles west of Lilesville. An advanced stage of decay to a depth of 15 to 20 feet is indicated.

FRANKLIN COUNTY.

About 4 miles northeast of Franklinton occur small exposures of a porphyritic biotite granite. The rock is coarse grained, light gray, and in an advanced stage of decay at the surface. The feldspar phenocrysts are large, pink, and more or less idiomorphic in form and contain inclusions of biotite. No stone has been quarried. A porphyritic tendency is indicated in the granite occurring west of Louisburg.

The fine-grained biotite granite gneiss (see pp. 125–129) quarried at Greystone, Vance County, to the north of the Franklinton porphyritic granite area, has a pronounced porphyritic tendency in many of the quarries.

PIEDMONT PLATEAU PORPHYRITIC GRANITES.

GENERAL DESCRIPTION.

Two facies of granite, porphyritic and even granular, are prominently developed over many parts of the plateau region. Usually they grade into each other. The even-granular granites of this region are described on pages 124–152. A pronounced zone of porphyritic granite extends in a northeasterly direction through a number of counties along the western margin of the Carolina igneous belt of the Piedmont region. It begins to the southwest in Gaston County, near Gastonia, the county seat, and passes northeastward through Iredell County, where large areas are exposed around Mooresville and Mount Mourne; thence to the west of Salisbury, in Rowan County, along Yadkin River, in Davie County, and to the southeast of Winston-Salem in Forsyth County. In Rowan County the porphyritic granite has a width of 4 to 8 miles. In places the feldspar phenocrysts almost entirely die out, reappearing within a short distance in proportions equaling and locally exceeding the groundmass.

Where observed within this area the porphyritic granite preserves nearly constant characteristics. It is a coarse-grained medium to dark gray porphyritic biotite granite. The feldspar phenocrysts are persistently marked by idiomorphic outlines and are of large size, measuring in extreme cases more than 2 inches in length by 1 inch across. They are usually white, though pink feldspars are not uncommon, and they almost invariably contain some included biotite as large in size as that of the groundmass constituent. Twinning after the Carlsbad law is very common and the cleavage is pronounced. Marked orientation of the phenocrysts was not apparent.

In the absence of exposures the porphyritic granite is readily traced by its decay. The feldspar phenocrysts are abundantly scattered over the surface in a partly kaolinized condition, and many of the individuals are split into smaller fragments along the cleavage lines.

A second very prominent area of porphyritic granite, similar to that described above, lies in Cabarrus County, north and northwest of Concord, the county seat. About 3½ miles southwest of Concord is an area of coarse-grained syenite (see p. 137), which possibly grades into even-granular and porphyritic granite to the northeast and southwest.

DESCRIPTION OF INDIVIDUAL AREAS.

GASTON COUNTY.

Beginning at Gastonia and extending for about 2½ miles east-northeastward along the Gastonia-Charlotte macadam road is a belt of gray coarse-grained porphyritic granite. The feldspars make up at least 50 per cent of the rock mass and in places more. The phenocrysts are white, opaque, and large, some of them measuring more than an inch in length. They are usually flat-tabular, and idiomorphic in outline and contain biotite inclusions. A tendency toward orientation in the phenocrysts is exhibited in places. The rock in an advanced stage of decay is exposed in shallow cuts along the road. The phenocrysts observe essentially the same position and characteristics in the decayed material as in the fresh rock, except that they are dull in luster and largely altered to kaolin. Only one quarry has been opened in the porphyritic granite of this area.

The *Jenkins quarry*, located 2 miles northwest of Gastonia, comprises two openings. The rock is a porphyritic biotite granite of gray color and medium grain, with a fairly well-defined schistose structure developed in a N. 10° E. direction. The granite readily splits along this direction into curbing 10 to 12 feet long, for which the stone is principally used.

The feldspar phenocrysts are somewhat sparingly distributed; both idiomorphic and allotriomorphic forms appear, the former exhibiting flat-tabular outlines and measuring as much as 2 inches long by half an inch across. The phenocrysts are further characterized by inclosures of biotite and are of faint pinkish color.

Thin sections show much lath-shaped plagioclase. Chlorite, a colorless mica, iron oxide, and some epidote occur as alteration products derived from biotite. The phenocrysts consist entirely of potash feldspar, and the larger individuals are characterized by micropoikilitic structure.

Two sets of vertical joints, spaced at wide intervals, strike N. 20° to 30° E. and N. 80° W.

IREDELL COUNTY.

Porphyritic granite constitutes the principal type of granite in the Mooresville area. It extends east of north from Mooresville along the Salisbury road for about 5 miles. To the south, southwest, and west of Mooresville it has been traced for approximately 3 miles in each direction. It is exposed in a number of large flat-surfaced outcrops near Mount Mourne, 2½ miles south of Mooresville. Over the entire area the porphyritic granite maintains remarkable uniformity in both color and texture.

Where exposed the groundmass of the porphyritic granite is a biotite granite of dark-gray color and medium-coarse grain. It is composed of the essential minerals feldspar, quartz, and biotite.

The phenocrysts are of potash feldspar, usually twinned on the Carlsbad law; are chiefly flat-tabular and idiomorphic in outline; range from one-half inch to 2 inches in length by one-eighth to three-eighths of an inch across; and are either white or pink. As a rule the phenocrysts do not grade into the groundmass constituent, and are without marked orientation so far as observed, though at several exposures a slight tendency toward it was somewhat apparent. The phenocrysts contain included biotite, much of it in bodies as large as that of the groundmass. The ratio of the phenocrysts to the groundmass is approximately 1 to 1, with but little variation from this in any of the outcrops examined.

In the fresh rock many of the phenocrysts are of a pronounced pinkish color, but in the weathered granite they are entirely white and opaque from partial kaolinization. Over much of the area the granite is more or less deeply decayed, and the texture of the rock is preserved in the decayed material. In such material the phenocrysts are usually white and unstained and with the loose scattered crystals over the surface they afford a means of readily tracing the underlying fresh granite.

The best exposures of the fresh porphyritic granite are north of Mount Mourne and at the Breed quarry, 1½ to 2 miles southwest of

Mooresville. Outcrops of the partly or completely decayed rock are numerous over the entire area.

A small opening was made in a flat-surfaced exposure of the porphyritic granite half a mile north of Mount Mourne, where a little stone was quarried prior to the civil war. Microscopically, the minerals of the rock at this locality are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, and biotite. Titanite, apatite, and magnetite occur as accessory minerals, together with a little secondary chlorite and epidote derived from the alteration of biotite. Microcline is the porphyritically developed feldspar and exhibits micropoikilitic structure. Intergrowths of quartz and feldspar are numerous.

At this point the porphyritic granite is cut by a dike of fine-textured dark blue-gray biotite granite similar to the even-granular granite quarried near Mooresville, described on page 143. The dike is irregular in outline, varying from 6 to 12 inches across, with a general northeast strike, and is regarded as an apophysis from the main body of the granite quarried near Mooresville.

The *Breed quarry*, 2 miles southwest of Mooresville, shows beautiful contacts between the fresh porphyritic granite and the even-granular granite. Thin sections of the porphyritic granite from the Breed quarry are identical in mineral composition with the Mount Mourne porphyritic granite described above. The field relations of the two granites in this area strongly indicate that they are not different facies of the same rock mass, grading one into the other, but that the even-granular granite is intrusive into the porphyritic granite, and is therefore younger.[a]

CABARRUS COUNTY.

Landers, a station on the main line of the Southern Railway in the extreme southern part of Rowan County, near the Cabarrus County line, is adopted for the name of a large area of porphyritic granite exposed over the middle northern part of Cabarrus County.

On Schulenberger Branch, where crossed by the Concord road, about three-fourths of a mile south of Landers, there are flat-surfaced exposures of a porphyritic biotite granite of gray color and medium-coarse grain. The rock can be traced continuously by scattered small outcrops of the moderately fresh granite and its residual material to a point within 4 or 5 miles north of Concord. The proportion of groundmass to phenocrysts is large and the porphyritic feldspars are white or very light in color. The phenocrysts exhibit both idiomorphic and allotriomorphic outlines, without apparent orientation. They are composed of potash feldspar and those of irregular outline pass by decreased size into the similar groundmass constituent. Biotite inclusions are common in the phenocrysts and twinning on the Carlsbad law is prevalent.

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[a] Bull. North Carolina Geol. Survey No. 2, 1906, pp. 88, 89.

A thin section cut from a specimen of the porphyritic granite 5½ miles north of Concord indicated a biotite granite composed principally of potash feldspar (orthoclase and microcline), much soda-lime feldspar (oligoclase), quartz, and biotite. The biotite is much altered to chlorite and is in places crowded with inclusions. The feldspar contains a considerable proportion of small included particles of black iron oxide. Crystals of titanite are noted here and there in the thin sections.

No openings have been made in the porphyritic granite. The vertical joints are spaced at wide intervals. Scattered dark-colored areas of biotite (knots) and local thin veins of feldspar are observed in the rock. Pyrite is sparingly developed in small scattered grains and crystals, but it has not been noted in sufficient amount in any exposures to injure the stone seriously.

ROWAN COUNTY.

Beginning about 2 miles northwest of Salisbury, on the Wilkesboro road, is an extensive belt of coarse-grained porphyritic biotite granite, which can be traced continuously by its residual material northwestward along the road to a distance of about 8 miles from Salisbury. The porphyritic granite grades in many places into an even-granular granite of the same composition. Exposures of the fresh rock were observed only at a point about 3 miles northwest of Salisbury, immediately on the road, where a small opening had been made and a little of the stone quarried for macadam.

The groundmass of the rock is a biotite granite of moderately dark-gray color and medium grain. The phenocrysts are composed of potash feldspar, usually idiomorphic in outline and twinned on the Carlsbad law. As a rule, they are very large, from 2 inches or more long by one-half to 1 inch wide. They contain inclusions of biotite and in one or two places show a tendency toward orientation.

The rock is deeply weathered into a light-gray granitic sand, in a few places deeply colored by staining from iron oxide. The large phenocrysts, more or less kaolinized, are rather thickly strewn over the surface and offer a very sure means of tracing the rock. Some of them are split into smaller pieces along the cleavage directions, distributed through the decayed granite in the same position as in the fresh rock.

DAVIDSON AND DAVIE COUNTIES.

About 3½ miles west of Lexington, on the Mocksville road, partly decayed light-gray biotite granite of fine to coarse grain, with a slight porphyritic tendency in places, is exposed. Within a short distance westward the rock becomes typically porphyritic and can be continuously traced along the road by means of its decayed material in Davie County to Advance and beyond, a distance of 18 miles west of Lexington. Exposures of the fresh granite were not seen, but the porphyritic texture of the fresh granite is preserved in the decayed product. In color the decayed granite ranges from light gray to yellowish red, with the feldspar phenocrysts still intact but much kaolinized. In the lighter-colored residual material the biotite has suffered but little alteration, but in the deeper-colored areas much chemical alteration of this constituent is evident.

The phenocrysts are mostly of large size and flat-tabular to irregular in outline, and they exhibit the usual Carlsbad twinning. Inclusions of biotite are conspicuous.

The decayed material indicates a porphyritic biotite granite, of medium-coarse grain, resembling in all respects the porphyritic granite of Gaston, Iredell, Cabarrus, and Rowan counties described above.

FORSYTH COUNTY.

About 5 miles south of Winston, near the Lexington road, an opening was made in porphyritic granite and the stone quarried for use in Winston-Salem.

The rock is a porphyritic biotite granite of light-gray color and medium-coarse grain. Most of the feldspar phenocrysts are roughly rounded and of irregular outline, and by decrease in size grade into the same groundmass constituent. Many of the phenocrysts, however, show idiomorphic, flat-tabular outlines, one-half inch in length by one-eighth inch across; they exhibit Carlsbad twinning and contain biotite inclusions.

The principal minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite. Secondary muscovite, chlorite, and epidote, with a slight sprinkling of minor accessories, complete the list of minerals. In the larger feldspar individuals the micropoikilitic texture is well developed, the inclosed minerals consisting largely of feldspar. Intergrowths of quartz and feldspar and of feldspars with each other are freely distributed through the thin sections.

The vertical joints strike N. 50° E. and N. 45° W. A slightly foliated structure is developed in the granite in places.

GUILFORD COUNTY.

The Guilford County granite area is a large one, extending from Summerfield to Friendship, a distance of 10 miles, and lying about 10 miles northwest and west of Greensboro. Several small openings have been made in the vicinity of Summerfield and Friendship to supply a local demand for stone.

The rock is a porphyritic biotite granite of variable gray color and medium to coarse grain. It grades into the even-granular granite at a number of points. The principal minerals are orthoclase, some microcline, plagioclase in variable amount, quartz, and biotite. Apatite, zircon, and titanite are the primary accessories, and chlorite and colorless mica the secondary minerals. The feldspar phenocrysts are both irregular, roughly rounded in outline and flat-tabular, half an inch to 2 inches long by half an inch wide, and many of them are twinned on the Carlsbad law.

Several dikes of diabase penetrate the granite between Summerfield and Friendship.

SUPPLEMENTARY NOTE.—In the table below are given the percentages of silica, alumina, lime, soda, and potash in feldspars quarried from pegmatite dikes in North Carolina.[a]

Analyses of North Carolina feldspars.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Silica (SiO_2)	64.25	63.52	63.55	62.95	64.75	65.15	64.55	64.85	65.18
Alumina (Al_2O_3)	18.34	21.20	20.20	19.66	19.24	19.04	22.26	19.90	21.60
Lime (CaO)	.08	Trace.	Trace.	Trace.	Trace.	.12	1.41	None.	.64
Soda (Na_2O)	5.95	3.62	6.65	7.64	7.85	7.00	7.91	10.04	8.35
Potash (K_2O)	11.66	9.50	8.73	8.39	7.55	7.28	3.94	2.91	.04

1. Young mine, Dobag, Yancey County.
2. Irby mine near Spruce Pine, Mitchell County.
3. Ray mine, near Burnsville, Yancey County.
4. Averys Meadow mine, Plumtree, Mitchell County.
5. Tolly Bend mine, near Micaville, Yancey County.
6. Flat Rock mine, Flat Rock, Mitchell County.
7. Charlie Robertson mine, near Micaville, Yancey County.
8. Wiseman mine, near Spruce Pine, Mitchell County.
9. Cloudland mine, near Bakersville, Mitchell County.

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[a] Pratt, J. H., Economic paper No. 6. North Carolina Geol. Survey, 1902, pp. 49-50.

CHAPTER V.

THE GRANITES OF TENNESSEE.

The occurrence of granite in Tennessee is limited to the extreme middle-eastern and northeastern portions of the State, immediately along the North Carolina boundary, in the rugged mountain belt. The areas, including the westward extensions of some of the principal ones in western North Carolina, are of minor extent. They include the Cranberry and Beech granites and Carolina gneiss in Carter and Johnson counties,[a] and the Max Patch and Cranberry granites in Cocke and Sevier counties.[b] According to Keith these are all of Archean age. They are described in some detail on pages 153–161.

Owing to the meagerness of the areas of granite and the general character of the granite itself, it is very doubtful if granite quarrying will ever assume any great importance in this State. At present the areas are somewhat inaccessible and much of the granite is not suitable for the better grades of work. Merrill states that quarries of a coarse dull-pink biotite granite have been opened recently on Ripshin Mountain, on Doe River.[c]

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[a] Keith, Arthur, Cranberry folio (No. 90), Geol. Atlas U. S., U. S. Geol. Survey, 1902.

[b] Keith, Arthur, Asheville folio (No. 116), Geol. Atlas U. S., U. S. Geol. Survey, 1904.

[c] Merrill, G. P., Stones for building and decoration, 3d ed., New York, 1903, p. 83.

CHAPTER VI.

THE GRANITES OF SOUTH CAROLINA.

THE SOUTH CAROLINA CRYSTALLINE REGION.

The South Carolina crystalline region embraces a roughly triangular area which is included within the fall line on the southeast, Savannah River and the northeastern boundary of Georgia on the southwest and west, and the southern boundary of North Carolina on the north. The fall line, characterized by extreme irregularity, extends in a general southwestward direction across the State, passing through or near Chesterfield, Kershaw, Camden, Columbia, and Trenton, S. C., and Augusta, Ga. (See Pl. XXI.)

The extreme northwestern portion of the crystalline region comprises a narrow belt (part of the Blue Ridge), not exceeding 30 miles wide, of mountainous topography, the higher peaks rising to an elevation of 3,500 feet. Between this mountainous belt on the northwest and the fall line on the southeast is included the greater portion of the crystalline region, the Piedmont province, which does not essentially differ from the parts of the same province to the northeast and southwest. Its principal features are the broad, rolling upland surface, the valleys carved in the upland, and the minor residual masses which rise above the upland.

According to Sloan, the higher elevations of the Piedmont region range from 700 to 900 feet above sea level and the beds of the major streams are 200 feet lower (500 to 700 feet). The surface gradually lowers toward the fall line to elevations of less than 120 feet in the major valley bottoms to 680 feet on the upland between Savannah and Congaree rivers, and to 597 feet between Wateree and Pedee rivers.[a]

The major rock types of the South Carolina crystalline region are similar to those of the southeastern Atlantic crystalline region in general, as described on pages 35–37. They include both igneous and sedimentary masses, usually much altered from metamorphism. The principal types comprise micaceous and hornblendic gneisses and schists, granites, and slates, with numerous masses of crystalline limestone, chiefly dolomitic, and quartzite. Surface volcanic rocks and their pyroclastic equivalents (tuffs), especially the latter, much

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[a] Sloan, Earle, A catalogue of the mineral localities of South Carolina: Bull. South Carolina Geol. Survey, ser. 4, No. 2, 1908, p. 408.

altered from metamorphism, are extensively developed in places. Intrusions in the form of dikes of acidic and basic composition cut the rocks of this crystalline complex. With the exception of the massive granites and the dikes of igneous rocks, the rock types mentioned above are greatly altered by metamorphic changes and usually show pronounced schistose structure.

At Hornsboro, in Chesterfield County, is a small area of Triassic (Newark) rocks composed of brownish-red to gray sandstones, penetrated by dikes of diabase. This is an extension into South Carolina of the Wadesboro, N. C., area of Newark rocks.

DISTRIBUTION OF THE GRANITES.

The granites of South Carolina are limited to the crystalline area, which includes the whole or a part of Abbeville , Anderson, Cherokee, Chester, Chesterfield, Edgefield, Fairfield, Greenville, Greenwood, Kershaw, Lancaster, Laurens, Lexington, Newberry, Oconee, Pickens, Richland, Spartanburg, Saluda, Union, and York counties. Some granite has been quarried—usually a very small quantity strictly for local use—in one or more localities in each of these counties, and during the summer of 1908 quarrying operations were in progress in nine of them. The principal producing areas were Columbia, in Richland County; Lexington, in Lexington County; Edgefield, in Edgefield County; Winnsboro, in Fairfield county; Heath Springs, in Lancaster County; and Beverly, in Pickens County.

SCIENTIFIC DISCUSSION.

MINERAL COMPOSITION.

The granites of South Carolina are mixtures of feldspar and quartz, with biotite as the third essential component. Muscovite as a primary constituent is practically absent in many of the granites. It occurs as a very subordinate constituent, associated with biotite, in a part of the granites of Edgefield, Fairfield, Oconee, and York counties, and as a principal constituent in a reddish-gray granite found near Liberty Hill village in Kershaw County. Hornblende has been noted in the granite of only one locality, 1 mile south of Winnsboro, on the Winnsboro-Rockton road. Thin sections of this granite reveal sufficient hornblende to designate the granite a hornblende-bearing biotite granite.

The feldspars include nearly equal mixtures of potassic (orthoclase and microcline) and lime-soda (plagioclase) varieties. Orthoclase is the dominant potassic feldspar, with microcline equal to or greater in amount in some sections and entirely absent in others. Microperthite, an intergrowth of orthoclase with a second feldspar (plagioclase), is very constantly present. Plagioclase is usually present, in most places being equal to or greater in amount than the potassic feldspar. This is shown by the high soda content in the table of chemical analyses given below, and is confirmed by the microscopic study of thin sections of the granites.

The granites contain, besides the principal constituents enumerated above, accessory apatite, zircon, magnetite, titanite, and rutile, together with secondary chlorite, epidote, and a light-colored mica, and locally some other minerals.

CHEMICAL COMPOSITION.

The subjoined analyses of even-granular and porphyritic granites and granite gneisses show the range in composition of the South Carolina granites. A study of the analyses indicates that these granites correspond closely in chemical composition with the granites of the southeastern Atlantic States in general. In conformity with the other granites described in this report the South Carolina rocks are soda-rich granites (quartz monzonites). In 13 of the 19 analyses soda (Na_2O) approximately equals or is but slightly less than potash (K_2O), in five soda exceeds potash, and in only one is there a great excess of potash over soda. On the basis of potash-soda ratio the South Carolina granites correspond more closely to quartz monzonites than to normal granites.

Another feature shown by these analyses is the constant presence of titanium in very appreciable amount, ranging in the form of TiO_2 from a minimum of 0.24 per cent to a maximum of 0.84 per cent. Manganese and phosphorus are also reported in every analysis, either in traces or in larger amounts.

Chemical analyses of South Carolina granites.[a]

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	68.70	68.71	68.80	68.90	69.52	69.74	70.11	70.20	70.54	70.77
Al_2O_3	15.49	15.41	15.73	15.75	16.77	13.72	15.76	14.22	14.56	14.89
Fe_2O_3	1.10	1.85	2.14	1.16	.95	3.64	1.07	1.14	1.06	.75
FeO	3.73	1.59	1.57	1.49	1.56		1.76	1.24	1.62	1.24
MgO	.86	1.25	1.16	.74	.75	.22	.62	.48	.78	.43
CaO	1.70	1.64	1.64	2.66	1.82	1.54	1.84	2.14	1.28	2.08
Na_2O	3.09	3.48	3.45	4.76	3.43	5.39	3.39	5.39	3.97	4.47
K_2O	3.36	4.61	4.54	3.49	4.10	4.98	4.27	4.82	5.37	4.70
Ignition	.81	.34	.33	.18	1.43	....	.45	.33	.27	.19
TiO_2	.84	.60	.45	.36	.36	....	.45	.24	.60	.36
MnO	Trace.	Trace.	Trace.	Trace.	Trace.	....	Trace.	Trace.	Trace.	Trace.
P_2O_5	Trace.	Trace.	Trace.	Trace.	Trace.	....	Trace.	Trace.	Trace.	Trace.
SO_3	.13	Trace.	Trace.	Trace.	Trace.	....	Trace.	Trace.	.06	Trace.
	99.51	99.46	99.81	99.49	99.69	99.23	99.72	100.20	100.11	99.88

[a] Sloan, Earle, op. cit., pp. 167–225, 250–255.

1. Porphyritic biotite granite, Clouds Creek, 4.7 miles north of Batesburg, Saluda County.
2. Porphyritic biotite granite, Flatrock (old Dekalb granite), Kershaw County.
3. Biotite granite, Cold Point station, Laurens County.
4. Biotite granite, Jackson quarry, 0.5 mile north of Clover, York County.
5. Biotite granite, Leitzsey quarry, 5 miles northeast of Newberry, Newberry County.
6. Biotite granite, Anderson quarry (Winnsboro Granite Company), 8.5 miles from Rion, Fairfield County.
7. Biotite granite, Excelsior granite quarry, 5.2 miles southwest of Heath Springs, Lancaster County.
8. Biotite granite, Flatrock quarry, 2 miles north of Carlisle, Union County.
9. Biotite granite, Benjamin quarry, 4 miles east-northeast of Greenwood, Greenwood County.
10. Muscovite-bearing biotite granite, Whiteside quarry, 2 miles west of Filbert, York County.

Chemical analyses of South Carolina granites—Continued.

	11.	12.	13.	14.	15.	16.	17.	18.	19.
SiO_2	70.90	71.20	72.19	72.22	73.26	62.34	65.72	68.15	73.10
Al_2O_3	15.25	17.04	14.06	14.51	15.39	17.22	17.22	14.30	13.82
Fe_2O_3	1.52	3.48	.70	1.28	1.24	1.75	1.70	2.44	.93
FeO	1.53		1.80	1.52		2.49	2.67	2.49	1.43
MgO	.63	.11	.84	.58	.38	1.30	1.45	1.04	.51
CaO	2.40	....	1.88	1.32	1.36	3.28	2.80	2.80	1.72
Na_2O	4.32	2.32	3.46	3.21	.55	5.28	3.68	3.80	3.04
K_2O	2.85	4.70	3.94	4.30	6.89	5.14	3.80	3.84	5.06
Ignition	.17	.63	.18	.52	....	.28	.35	.28	.23
TiO_2	.42	....	.48	.24	....	.60	.72	.60	.24
MnO	Trace.	....	.16	Trace.	....	Trace.	Trace.	.11	Trace.
P_2O_5	Trace.	....	Trace.	Trace.	....	Trace.	Trace.	Trace.	Trace.
SO_3	Trace.	....	Trace.	....	....	Trace.	.08	Trace.	Trace.
	99.99	....	99.69	99.70	99.07	99.68	100.19	99.85	100.08

11. Muscovite-bearing biotite granite, Blair quarry, 0.4 mile east of Blair, Fairfield County.
12. Biotite granite, Keystone Granite Company's quarry, 2.5 miles north of Pacolet, Spartanburg County.
13. Biotite granite, Ross quarry, near Columbia, Lexington County.
14. Biotite granite, Southern Granite Company's quarry, 6.8 miles southwest of Heath Springs, Kershaw County.
15. Biotite granite, Rion quarry (Winnsboro Granite Company), Rion, Fairfield County.
16. Biotite granite gneiss, Hanckel quarry, 1.7 miles southwest of Pendleton, Anderson County.
17. Biotite granite gneiss, Ware Shoals, Laurens and Abbeville counties.
18. Biotite granite gneiss, Beverly quarry, Beverly station, Pickens County.
19. Biotite granite gneiss, Bates quarry, near Batesburg, Lexington County.

TYPES OF GRANITE.

GENERAL STATEMENT.

The granites of South Carolina, in common with those of the southeastern Atlantic States in general, vary in structure from massive to schistose and in texture from even granular to porphyritic. Accordingly, three types of the rocks may be distinguished: (1) Even-granular massive granites, (2) porphyritic granites, and (3) schistose or foliated granites or granite gneisses.

The even-granular and porphyritic granites are textural variations of the same rock mass and are locally present in the same quarry, but in such places the porphyritic texture is likely to be of a less pronounced type than is observed elsewhere. The granite gneisses were derived from massive granites, from which they differ principally in the pronounced schistose structure secondarily induced in them by dynamic metamorphism.

As described above, under "Mineral composition," the South Carolina granites are, with one exception, mica granites, and are prevailingly biotite granites. Sloan[a] reports the occurrence of both augite and hornblende granites in the State, but remarks that they are of doubtful commercial value, especially the augite granite. The writer did not observe the occurrence of either one of these types.

On the basis of mineral composition, then, the South Carolina granites are divisible into (1) biotite granite, which may contain little or no muscovite in addition to biotite, and under which the greater part of the granites of the State may be grouped; (2) muscovite-bearing biotite granite, of which there are only a few representatives; and (3) muscovite granite, of which the single occurrence near Liberty Hill village, Kershaw County, is the only representative yet observed.

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[a] Sloan, Earle, op. cit., pp. 170–171.

EVEN-GRANULAR GRANITE.

Even-granular granites have wide but variable distribution throughout the crystalline area of the State. They vary from fine to medium grained, being rarely coarse grained. Hardly without exception they are of some shade of gray in color; light, medium, and dark blue-gray shades are common. In many localities a part of the feldspathic constituent is of slight or pronounced red color and imparts a mixed reddish-gray color to the rock, the depth of which is proportional to the intensity of the red of the feldspar.

With but few exceptions the granites are biotite granites. Muscovite, though present in places, is very subordinate, and hornblende is practically lacking. The principal minerals are orthoclase, microcline, plagioclase (oligoclase), quartz, biotite, a little muscovite, magnetite, apatite, and zircon. Titanite is a common accessory in many localities. The usual secondary minerals occur, chief among which are chlorite, epidote, muscovite, and kaolin. These are the normal minerals in granite and are so familiar that details are unnecessary here.

Micropegmatitic intergrowths of the quartz and the feldspars are common, indicating that the period of formation of the quartz clearly began before that of the feldspar closed. Orthoclase is the dominant potash feldspar, but microcline, which is usually present but variable in amount, may exceed it. Carlsbad twins are frequently seen both in thin sections and in hand specimens of the rocks. The plagioclase is invariably characterized by polysynthetic twinning striæ. Extinction angles of the plagioclase usually indicate oligoclase. The presence of considerable lime in the analyses tends to confirm the microscopic study. Microperthitic intergrowths of the feldspars are indicated in most of the thin sections studied. Many of the larger feldspar individuals are micropoikilitic, the inclosures consisting of both quartz and feldspar.

Biotite, though always present, is subject to some variation in amount. It is of deep-brown color and strongly pleochroic. It is usually altered to chlorite and less commonly to epidote; both minerals are present, chlorite being the more abundant. Muscovite, where present, is somewhat closely associated with biotite.

Magnetite, apatite, zircon, and titanite are the most common primary accessories. Much of the magnetite shows crystal boundaries and it occurs locally in irregular crystalline grains. The apatite and zircon present no noteworthy features. Titanite is present in many of the sections, both as irregular grains and aggregates and as rhombic crystals. It varies from nearly colorless to reddish brown, with noticeable pleochroism in the deeper-colored individuals.

PORPHYRITIC GRANITE.

Porphyritic granites are common over many parts of the South Carolina crystalline region, but extensive continuous areas of them in which pronounced porphyritic texture is developed are apparently less numerous than in Georgia and North Carolina. Though porphyritic texture is freely developed in many of the granite areas, it either grades within rather short intervals into the more dominant even-granular texture or else is not of a pronounced type. In some areas the ratio of phenocrysts to groundmass is very small—that is, the phenocrysts are not abundant and are scattered irregularly at wide intervals through the groundmass. In other areas where the phenocrysts are abundant they may grade into the groundmass feldspar, thus imparting to the rock a less pronounced porphyritic texture than if the phenocrysts were sharply differentiated. There are exceptions, however, and typical porphyritic granites occur in which the phenocrysts are sharply defined from the similar groundmass constituent.

Like the even-granular granites into which they grade, the porphyritic granites are biotite granites and differ from the former only in texture. The porphyritically developed mineral is potash feldspar. The phenocrysts vary in size, form, and color. They rarely exceed 1 inch in length, are both of irregular (allotriomorphic) and regular (idiomorphic) outline, and are white or pink in color. They are in places twinned on the Carlsbad law, and inclusions of biotite in them are common. Marked orientation of the phenocrysts has not been observed in any of the areas.

GRANITE GNEISS.

The gneisses quarried in South Carolina and described in this bulletin have closely similar chemical and mineral compositions to the massive granites. The principal minerals are orthoclase (largely microperthite), microcline, soda-lime feldspar (oligoclase), quartz, biotite, a little muscovite, apatite, zircon, titanite, and secondary chlorite and epidote. Granulation of the quartz and the feldspar is usually pronounced, and orientation of the biotite is shown. The only essential difference between the gneisses and the massive granites is a structural one—the gneisses are schistose. For these reasons and from the field evidence, these gneisses are believed to have been derived from original granites and are therefore designated granite gneisses.

The banding of the gneisses may be fairly regular, but as a rule it is rather irregular and highly contorted; in either case the bands are alternating ones of light (chiefly feldspar and quartz) and dark (chiefly biotite) minerals. The individual bands are subject to considerable variation in thickness. Like the massive granites, the gneisses vary in color and texture.

Both even-granular and porphyritic textures are common, the latter in places imparting a true augen gneiss appearance to the rock. The porphyritic mineral is invariably a potash feldspar, commonly microcline, and locally it is of pronounced reddish or pink color.

Of the numerous granite gneisses occurring in the State, probably that quarried by the Greenville Granite Company at the Beverly quarry, in Pickens County, is one of the most typical. It very closely resembles the well-known contorted biotite granite gneiss extensively quarried at Lithonia, Ga. (pp. 253–262), and a similar one composing Rocky Face Mountain in Alexander County, N. C. (pp. 152–153).

STRUCTURAL FEATURES OF THE GRANITES.

DIKES.

Dikes of granitic composition in the South Carolina quarries are of two kinds—extremely fine-grained granite (aplite) and very coarse grained granite (pegmatite). Dikes of basic composition, chiefly diabase, have also been observed penetrating the granites in a number of localities, but have not been noted at any of the quarries, though they occur not uncommonly in the granite quarries of North Carolina (p. 118).

APLITE.

Aplite dikes are present only here and there in the South Carolina granites. They have been noted by the writer only at the Smith Branch (County) quarry, near Columbia; the Anderson quarry, 5 miles west of Rion, in Fairfield County; and the Casparis Stone Company's quarry, near Lexington.

At the Smith Branch quarry aplite dikes, ranging in thickness from a fraction of an inch to 4 feet, are rather numerous. In color they are reddish brown, and in texture are so dense and fine grained that the mineral particles can not be distinguished with the unaided eye. The largest dike, 4 feet wide, is exposed on opposite sides of the opening (about 50 feet wide) and trends in a northeast-southwest direction, observing a general southwesterly steep dip. It consists of potash feldspar (orthoclase chiefly, with some microcline), soda-lime feldspar (oligoclase), quartz, a little biotite, accessory apatite, and secondary chlorite and epidote.

At the Anderson quarry there are several aplite dikes which range in thickness from 1 to 12 inches. Most of these are associated with pegmatite dikes, as banded aplite—pegmatite, after the fashion shown in figures 16 and 17, page 188. The aplite proper is very fine grained and light gray, with scant biotite visible to the unaided eye. The aplite consists of potash feldspar (microcline and orthoclase, partly perthite), some soda-lime feldspar (oligoclase), quartz, very little biotite and muscovite, accessory zircon, and secondary chlorite and epidote. Muscovite is partly secondary.

At the Casparis Stone Company's quarry a single aplite dike 2 inches wide was noted. The dike is very fine grained and light gray and contains no mica visible to the naked eye.

PEGMATITE.

Pegmatites are present in great numbers in some quarries and practically absent in others. They do not attain very large size, ranging from a fraction of an inch to 18 inches in width, but are usually narrow. Nowhere do they seriously interfere with quarrying operations. They are of granitic composition, consisting of the usual coarse crystallizations of feldspar and quartz, with subordinate mica, usually biotite, though some muscovite is commonly present. In the Peek quarry, near Pacolet, black tourmaline is a constituent of some of the pegmatites.

The feldspar of the pegmatites is generally white but locally of reddish or pink color. It shows good cleavage development and is twinned on the Carlsbad law. It is the most abundant constituent and is composed usually of potash feldspar (orthoclase or microcline, or both) and a less amount of acidic soda-lime feldspar.

The pegmatites apparently do not conform to any fixed direction or directions of strike, but show great variation. In the large exposures of granite on the Adams place near Clover, York County, faulting of the pegmatites was observed at one point, the displacement amounting to about 12 inches.

Over parts of the crystalline area, notably in Abbeville, Anderson, Greenville, Oconee, and Pickens counties, the pegmatites assume large dimensions, being 9 to 20 feet thick. Several of these dikes have become of economic importance within recent years for their mica and feldspar content, more especially the mica. As is indicated in the analyses below, the feldspar of these pegmatites belongs to the potassic variety.

Analyses of feldspar from South Carolina pegmatites.[a]

	1.	2.	3.	4.
SiO_2	60.79	62.26	65.00	67.30
Al_2O_3	22.57	20.41	19.45	18.21
Fe_2O_3	.18	.31	.71	.79
CaO	.24	.19	.18	.14
MgO	.23	.78	.13	.14
Na_2O	2.72	1.41	2.02	2.41
K_2O	11.01	12.71	11.34	11.14
Ignition	1.90	1.54	.63	.06
TiO_2	....	Trace.	Trace.	Trace.
P_2O_5	.09	....	....	....
SO_3	Trace.	....	Trace.	....
	99.73	99.61	100.19	100.19

[a] Sloan, Earle, op. cit., pp.142-149.

1. Potash feldspar from the Miller place, 8.5 miles S. 23° E. of Greenville, Greenville County, S. C.
2. Potash feldspar from point 12.5 miles northwest of Walhalla, Oconee County, S. C.
3. Potash feldspar from point 3.7 miles N. 71° W. of Pickens, Pickens County, S. C.
4. Potash feldspar from old powder mill, Oconee County, S. C.

QUARTZ VEINS.

Quartz veins are exceptional in the South Carolina granite quarries but have general though variable distribution throughout the crystalline area of the State. The few small ones observed in several of the quarries are unimportant and do not merit description. The quartz veins attain considerable size in many localities beyond the quarry limits, notably near Saluda in Saluda County, Oldtown in Newberry County, Ridgeway in Fairfield County, and Kings Creek in Cherokee County.

JOINTS.

Two systems of joints intersect the granite of the South Carolina quarries—a vertical set and a horizontal set. These not everywhere have the same degree of development, nor are the two systems present in all the quarries.

VERTICAL JOINTS.

The most common type of joint has an approximate vertical position, but joints with other inclinations (50° to 60°) occur. As a rule the joints are straight, but here and there they are curved or show other irregularities. The spacing of the joints varies greatly. The large number of measurements made indicate that the spacing of the joints, where well developed, is usually between 2 feet and 8 feet. In some quarries, however, zones of close jointing were observed, and the spacing was measured in inches. In others the joints were 30 to 50 feet or more apart.

Measurement made by compass of the strike of joint courses at fourteen South Carolina granite quarries yielded the following results:

N. 5°-10° E.
N. 20°-35° E.
N. 40°-50° E.
N. 60°-70° E.
N. 3°-10° W.
N. 20°-35° W.
N. 45°-60° W.
N. 65°-80° W.
East-west.
North-south.

In the northeast quadrant the joints which extend approximately north-northeast and east-northeast are of about equal development; in the northwest quadrant those which extend approximately west-northwest form the dominant system. Only a few of the joints measured extend east-west and north-south.

HORIZONTAL JOINTS.

Horizontal joints which, in general, follow the surface configuration of the rock are less commonly developed in the granite of the South Carolina quarries than at the quarries of the other Southern States. In some of the South Carolina quarries no horizontal joints were observed. This system of joints is especially well developed in the quarries of Morris & Co., near Columbia; the Keystone and Peek quarries, near Pacolet; and the Benjamin quarry, north of Greenwood. They are apparently surface phenomena and diminish in number rapidly with increasing depth. The spacing between the joints is invariably closest nearest the surface, ranging from a few inches to 8 feet.

SLICKENSIDES.

Polished and striated or grooved faces (slickensides) characterize many of the joints at the quarries, indicating movement in the rocks. This movement may have been caused by more or less faulting along the joint directions; if so, further evidence of it is lacking, as discontinuity in the granite masses along the joints has not been observed. A thin veneer or coating of white, reddish, and yellowish mineral substance is developed on the faces of many of the joints. It is derived probably from the original granite minerals by the rubbing of the walls on each other.

BASIC SEGREGATIONS (KNOTS).

Dark basic segregations (knots), so common in granite and believed to have formed from the cooling magma, have but scanty development in most of the South Carolina granites. They were not observed at all at many of the quarries, and only here and there at the other quarries with perhaps one or two exceptions. They are of small size, ranging from a fraction of an inch to several inches across, and usually of irregular oval outline. They are invariably of darker color and finer grain than the inclosing granite and are composed of dominant biotite with less quartz and feldspar.

INCLUSIONS.

Inclusions of foreign (country) rock incorporated into the granite during its intrusion are exceptional in the South Carolina quarries. The only such inclusion noted by the writer is at the quarry of the

Cold Point Granite Company, near Cold Point station, in Laurens County. In the main quarry opening is a mass of thinly but perfectly foliated, nearly black biotite gneiss about 30 feet long and 15 feet wide. It is entirely surrounded by the massive granite, and where observed the contacts between the two rocks are pronounced and sharp. The gniess inclusion is composed essentially of dominant black lustrous biotite, white feldspar, and a little quartz. It has a pronounced porphyritic texture in places.

PHYSICAL TESTS.

SPECIFIC GRAVITY AND ABSORPTION.

Tests of the specific gravity and the ratio of absorption of the South Carolina granites have been made by Earle Sloan, of the South Carolina Geological Survey, as follows:

Specific gravity and ratio of absorption of South Carolina granites.[a]

Rock.	Locality.	Specific gravity.	Ratio of absorption.
Biotite granite	Benjamin quarry, Greenwood County	2.65	....
Do.	Cold Point station, Laurens County	2.65	0.344
Porphyritic biotite granite	Clouds Creek, Saluda County	2.73	[b] 3.41
Biotite granite	Brown quarry, Newberry County	2.64	.405
Do.	Leitzsey quarry, Newberry County	2.65	.57
Do.	Flat Rock quarry, Union County	2.63	.389
Do.	Blair quarry, Fairfield County	2.66	.314
Do.	Strother quarry, Fairfield County	2.66	.247
Do.	Ross quarry, Lexington County	2.68	....
Do.	Whitesides quarry, York County	2.65	.292
Do.	Anderson quarry, Fairfield County	2.64	.440
Do.	Leiper-Davis quarry, Fairfield County	....	.338
Do.	Rion quarry, Fairfield County	2.62	.360
Do.	Jackson quarry, York County	2.66	.468
Muscovite granite	Liberty Hill, Kershaw County	2.62	.43
Biotite granite	6.8 miles S. 45° W. of Heath Springs, Kershaw County	2.63	.310
Do.	Excelsior quarry, Lancaster County	2.66	.380
Porphyritic biotite granite	Flat Rock, Cleyburn, Kershaw County	2.65	.129
Do.	Oro quarry, Chesterfield County	2.66	....
Biotite granite gneiss	Pendleton quarry, Anderson County	2.68	.288
Do.	Beverly quarry, Pickens County	2.66	.398
Do.	Ware Shoals, Laurens and Abbeville counties	2.68	.321
Do.	Paris Mount Granite Co., Greenville County	2.72	.304
Do.	Bates quarry, Lexington County	2.64	.202

[a] Sloan, Earle, op. cit., pp. 174-225.

[b] Probably a misprint for 0.341.

Examination of the table shows the range in specific gravity to be from 2.62 in the massive fine-grained granites of Fairfield County to 2.73 in the coarse-grained porphyritic biotite granite of Clouds Creek. Saluda County, and in ratio of absorption from 0.129 in the porphyritic granite of Kershaw County to 0.57 in the massive fine-grained granite of Newberry County.

COMPRESSIVE STRENGTH.

Tests to ascertain the compressive or crushing strength have been made, so far as the writer is aware, on very few of the South Carolina granites. Through the courtesy of Mr. B. H. Heyward, general manager of the Winnsboro Granite Corporation, the results of four tests made by the United States Ordnance Department to determine the compressive strength of the gray granite of the Rion quarry are given below.

Compressive strength tests of granite from Rion quarry, South Carolina.

Dimensions.		Sectional area.	First crack.	Ultimate strength.	
Height.	Compression surface.			Total.	Per square inch.
Inches.	*Inches.*	*Sq. in.*	*Pounds.*	*Pounds.*	*Pounds.*
3.55	3.41x3.54	12.07	317,000	386,000	31,980
3.53	3.57x3.51	12.53	350,000	369,900	29,520
3.54	3.50x3.53	12.36	350,000	417,000	33,740
3.56	3.54x3.54	12.53	305,000	325,000	25,940

Sloan[a] gives the minimum, maximum, and average results of four tests made by the United States Ordnance Department to determine the compressive strength of the blue granite of the Anderson quarry, as 24,700, 26,080, and 25,585 pounds per square inch, respectively.

Tests to determine the compressive strength of the Keystone Granite Company's gray granite, near Pacolet station, in Spartanburg County, gave 21,420 pounds per square inch.[b]

INDIVIDUAL QUARRY AREAS.

DISTRIBUTION.

The map (Pl. XXI) shows the location of the principal quarries or prospects, which include 33 separate openings. Of these 11 were operated in 1908. The principal quarries are on or near railroads. A few are located some distance from the principal railroad lines, but most of these are connected with the main lines by spur tracks. The names and locations of these quarries are given in the subjoined list.

Granite quarries in South Carolina.

Name.	County.	Location.
Quarries operating during 1908.		
Anderson (Winnsboro Granite Corporation).	Fairfield	8.5 miles west of Rion.
Beverly (Greenville Crushed Stone Company).	Pickens	Beverly.
Casparis Granite Company	Lexington	1.5 miles, N. 75° E., of Lexington.
Cold Point Granite Company	Laurens	Cold Point.
County (Smith Branch)	Richland	2 miles, N. 25° W., of Columbia.
Entrekin	Laurens	0.7 mile east of Graycourt.
Excelsior (Southern Granite Company)	Lancaster	5.2 miles southwest of Heath Springs.
Lipscomb (Morris & Co.)	Richland	Columbia.
Rion (Winnsboro Granite Corporation)	Fairfield	Rion.
Ross	Lexington	2 miles south of Columbia.
Whittle (Moore Creek)	do	4 miles northwest of Batesburg.

[a] Sloan, Earle, op. cit., p. 210.

[b] Idem, p. 198.

Granite quarries in South Carolina—Continued.

Name.	County.	Location.
Quarries operated prior to 1903.		
Bates	Lexington	1 mile north of Batesburg.
Bauman	Greenville	Greenville.
Benjamin	Greenwood	0.5 mile, N. 10° W., of Quarry.
Blairs	Fairfield	Blairs.
Bordeaux	Abbeville	Bordeaux.
Bowling Green	York	Bowling Green.
Edgefield	Edgefield	3 miles east of Edgefield.
Flat Rock	Union	2 miles north of Carlisle.
Happerfield	York	1.5 miles southeast of Yorkville.
Jackson	do	0.5 mile north of Clover.
Keystone Granite Company	Spartanburg	2.5 miles, N. 20° W., of Pacolet.
Leiper-Davis	Fairfield	5.5 miles northeast of Alston.
Leitzsey	Newberry	5 miles northeast of Newberry.
Oro	Chesterfield	9 miles west of Ruby.
Pacolet Granite Company (Johnson)	Spartanburg	0.75 mile northwest of Pacolet.
Pendleton	Anderson	1.7 miles southwest of Pendleton.
Shelor	Oconee	1 mile west of Walhalla.
Stewart	Fairfield	2.5 miles west of Rockton.
Strothers	do	Strothers.
Ware Shoals	Abbeville	6 miles northeast of Donalds.
Westminster	Oconee	Westminster.
Whitesides	York	3 miles west of Filbert.

DESCRIPTIONS OF QUARRIES.

ABBEVILLE COUNTY.

The *Bordeaux quarry* is located several hundred feet north of Bordeaux station. The writer was unable to visit this quarry, and the description which follows is taken from Sloan's report.[a] The principal type of rock is a biotite granite gneiss of gray color and fine grain, but a fair proportion of the quarry face is a massive granite of light-gray color and fine grain. The minerals are potash feldspar (orthoclase and microcline), a little soda-lime feldspar (oligoclase), quartz, biotite, and muscovite, together with accessory apatite and magnetite and secondary chlorite and kaolin. Pegmatite dikes and knots occur. The quarry has not been worked for some time.

The *Ware Shoals Manufacturing Company's quarry* is located at Ware Shoals, on Saluda River, about 6 miles northeast of Donalds. The rock is a biotite granite gneiss of gray color and fine grain. The principal minerals are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory apatite, zircon, and magnetite. A chemical analysis of the granite quarried adjacent to the power house at Ware Shoals is given on page 175 (No. 17). According to Sloan the absorption ratio of this granite is 0.321 and the specific gravity 2.68.

ANDERSON COUNTY.

No granite has been quarried in Anderson County in recent years. The *Hanckel quarry*, about 2 miles southwest of Pendleton, was last worked, according to the owner, C. Hanckel, about fifty years ago, to supply stone for the construction of culverts and bridges on the Blue Ridge Railway. The rock varies from a porphyritic biotite granite of reddish-gray color and medium-coarse grain to a biotite granite gneiss of light-gray color and fine grain. The principal minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and accessory apatite, titanite, and magnetite. The porphyritic feldspar is reddish and is commonly twinned on the Carlsbad law. A chemical analysis of this granite is given on page 175 (No. 16). According to Sloan the absorption ratio of the porphyritic granite is 0.288 and of the granite gneiss 0.448. The specific gravity of the granite is 2.68.

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[a] Sloan, Earle, op. cit., pp. 182-183

CHESTERFIELD COUNTY.

The *Oro quarry* is located 9 miles west of Ruby. The rock is reported to be a biotite granite of red-gray color and of coarse-grained to porphyritic texture. According to Sloan the feldspars are red, imparting a similar color to the granite, and partial alteration to epidote (epidotization) in some portions of the rock affords a greenish tint which heightens the effect. The granite has a specific gravity of 2.66, and is said to be susceptible of an excellent polish.

EDGEFIELD COUNTY.

The *Edgefield quarry* is about 0.5 mile north of the Edgefield-Trenton Railway, 3 miles east of Edgefield, and about the same distance from Trenton. The rock is a biotite granite of uneven color, usually pinkish gray, and medium grain. Its principal minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, a little biotite, apatite, and garnet. The feldspar has a faint reddish cast. The quartz is decidedly smoky and ranges from minute grains up to irregular masses an inch or more across. Biotite occurs in very subordinate quantity. Red garnets are visible in the hand specimens.

The quarry is about 700 feet long from north to south by about 100 feet wide and from 50 to 60 feet deep. The abundant quartz streaks or masses in this granite render it unsuitable for dimension stone. The product has been used principally for government jetty work at Charleston and Georgetown, S. C.

On the west side of the town of Edgefield an irregular muscovite-bearing biotite gneiss of dark-gray color and porphyritic texture has been quarried. The porphyritic feldspars are without distinct crystal boundaries, usually show good cleavage, and are pink in color.

FAIRFIELD COUNTY.

The granites of Fairfield County, especially those of the Rion and Anderson quarries of the Winnsboro Granite Corporation, are probably the South Carolina granites best known beyond the limits of the

State. They are mica granites but show variation in color and texture and are naturally grouped commercially into those most desirable for (*a*) building stone and (*b*) monumental stock. The product from the Rion quarry (gray granite) is used chiefly as a building stone; that from the Anderson quarry (blue-gray granite) is used exclusively for monuments. These two quarries were the only ones operating in Fairfield County at the time of examination in July, 1908.

The *Rion quarry* is located at Rion, 5½ miles southwest of Winnsboro, and is connected by a standard-gage spur track with Rockton, a station on the Columbia, Spartanburg and Asheville division of the Southern Railway 4½ miles to the east. (See Pl. XXII, *A*.)

The rock is a biotite granite of light-gray color and medium grain. Its minerals are potash feldspar (orthoclase, in large part intergrown with plagioclase as microperthite, and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, and colorless mica. Intergrowths of feldspar (microperthite) and of feldspar and quartz (micropegmatite) are abundant. The potash feldspar shows Carlsbad twinning. Inclosures of irregular rounded quartz, feldspar, and quartz-feldspar intergrowths (micropegmatite) are numerous in the larger feldspar individuals. The soda-lime feldspar shows more alteration than the potash varieties, chiefly into kaolin and colorless mica.

The following chemical analysis of the granite was made by Booth, Garrett & Blair, of Philadelphia, for the corporation:

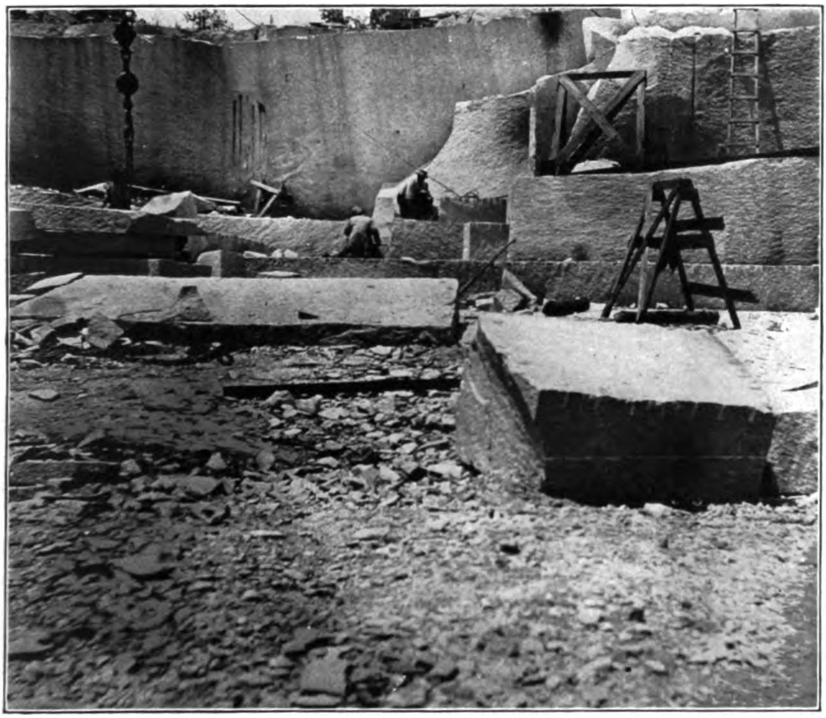
Analysis of granite from Rion quarry.

Silica (SiO_2)	73.26
Alumina (Al_2O_3)	15.39
Iron oxide (Fe_2O_3)	1.24
Magnesia (MgO)	.38
Lime (CaO)	1.36
Soda (Na_2O)	.55
Potash (K_2O)	6.89
	99.07

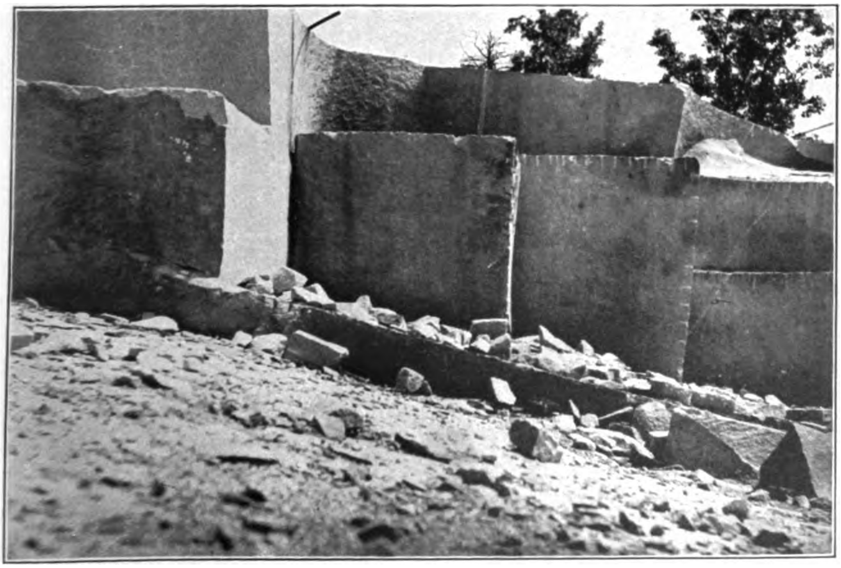
The specific gravity is 2.62. Tests of the compressive strength are given on page 183.

The quarry was opened about 1883, but systematic quarrying did not begin until fifteen years later. The quarry face is 300 feet long and 20 feet deep. (See Pl. XXII, *B*.) There is no stripping in the direction of working of the present quarry face. In other places the granite is decayed to a depth of 3 to 6 feet.

The principal set of vertical joints, striking approximately north and south, with a dip of 65° E., are widely spaced. Their faces are slickensided, and in places there is an abundant development of pyrite.



A. RION QUARRY OF WINNSBORO GRANITE CORPORATION, NEAR WINNSBORO, S. C.



B. NEAR VIEW OF QUARRY FACE IN RION QUARRY, NEAR WINNSBORO, S. C.

Knots are abundant in a few places and are of irregular shapes (rounded to much elongated, stringer-like forms) and sizes.

The working qualities of the granite are excellent and it is splendidly adapted to architectural work, for which it has had an extensive sale, as indicated in the following list of prominent structures in which it has been used: United States court-house and post-office buildings, Wilmington, N. C., Asheville, N. C., Statesville, N. C., and Opelousas, Ala.; post-offices, Charleston, S. C., Durham, N. C., Chillicothe, Ohio, Traverse City, Mich., Florence, S. C., and Charlottesville, Va.; bank building, Goldsboro, N. C.; Fidelity Title and Trust Company Building and Hussey Building, Pittsburg, Pa.; New Land Title and Trust Company Building, Philadelphia, Pa.; United States custom-house, Baltimore, Md.; building No. 1, commandant's office, navy-yard, Charleston, S. C.; Fairmont Trust Company, Fairmont, W. Va.; and Empire Bank Building, Clarksburg, W. Va.

In addition to its principal use in architectural work, the product is used for monument bases. The dry docks at Charleston, S. C., were built of this stone, 200,000 cubic feet being used. Extensive cutting and polishing yards are operated at the quarry.

The *Anderson quarry* is about 6 miles west of Rion, and is connected by a standard-gage track via Rion with Rockton, on the Southern Railway (Columbia, Spartanburg and Asheville division).

The rock is a biotite granite of dark blue-gray color and fine grain. It is closely similar to the dark blue-gray granites at Oglesby, Ga., (p. 218); at Heath Springs (Excelsior quarry), S. C. (p. 191); and at Richmond and Fredericksburg, Va. (p. 76). Of these, the granite at Heath Springs is the finest grained. The minerals of the Anderson rock are potash feldspar (orthoclase and much microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and magnetite and secondary chlorite and colorless mica. The orthoclase is partly intergrown with plagioclase as microperthite; the oligoclase is altered in part to a white mica and kaolin and the biotite to chlorite. Intergrowths of quartz and feldspar (micropegmatite) occur. Carlsbad twinning is observed in the potash feldspar.

The following analysis of the granite was made by Booth, Garrett & Blair, of Philadelphia, for the corporation:

Analysis of granite from Anderson quarry.

Silica (SiO_2)	69.74
Alumina (Al_2O_3)	13.72
Iron oxide (Fe_2O_3)	3.64
Magnesia (MgO)	.22
Lime (CaO)	1.54
Soda (Na_2O)	5.39
Potash (K_2O)	4.98
	99.23

The specific gravity is 2.64. Four tests of compressive strength of granite from the Anderson quarry, made by the United States Ordnance Department, gave the following results: Maximum, 26,080 pounds per square inch; minimum, 24,700 pounds; average, 25,585 pounds.

The quarry, opened about 1898, comprises a number of openings made in a large granite boss which rises to an elevation of nearly 100 feet above Mill Creek. The angle of slope averages from 10° to 20°, flatter in some places and steeper in others. No stripping is required over much of the boss.

The vertical joints strike N. 20° E., N. 35° to 40° E., N. 45° to 50° W., and N. 80° W. and are spaced at varying intervals. Several zones of close jointing were observed in places where the granite had not been opened. Pegmatite dikes, from a fraction of an inch to 8 inches thick and composed of white feldspar, glassy quartz, and scant biotite, occur in the granite. Aplite dikes, up to 12 inches thick, of light-gray color and fine grain and containing scant biotite, are also present. In some places the aplites and pegmatites are banded, as shown in figures 16 and 17. The principal banded aplite-pegmatite in the large opening strikes N. 65° W. There are a few small knots composed entirely of biotite.

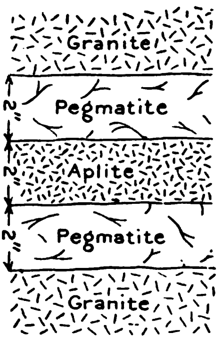


FIGURE 16.—Banded aplite-pegmatite at Anderson quarry, near Rion, S. C.

The granite is uniform in color and texture, possesses good working qualities, is susceptible of a high polish, and is admirably adapted to monumental purposes. The product is used chiefly for monumental stock, and is reported to have been so used in twenty-four States.

The *Strother quarry* is located half a mile south of Strother, on the east side of the Columbia, Spartanburg and Asheville division of the Southern Railway, with which the quarry is connected by a spur track. The rock is a biotite granite of light-gray color and irregular fine to coarse grain. Its minerals are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, biotite, a little muscovite, and accessory apatite and magnetite. The product has been used for rubble masonry at the Charleston navy-yard.

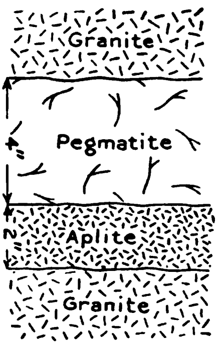


FIGURE 17.—Banded aplite-pegmatite at Anderson quarry, near Rion, S. C.

The *Blair quarry* is about half a mile east of Blair, a station on the Columbia, Spartanburg and Asheville division of the Southern Railway. The rock is a biotite granite of gray color and fine grain, with a porphyritic tendency in places. The minerals are the same as those at the Strother quarry. A chemical analysis of this granite is given on page 175 (No. 11). Its specific gravity is 2.66. A few pegmatite dikes and knots occur in the granite.

The *Leiper-Davis quarry*, comprising two openings about 500 feet apart, is located about 5 miles northeast of Alston, close to Little River. The rock is a biotite granite of medium-gray color and medium-fine grain. The principal minerals are potash and soda-lime feldspars, quartz, and biotite. The granite possesses good working qualities, is susceptible of a good polish, and was extensively used at one time for monumental stock.

The *Stewart quarry* is located about 2½ miles west of Rockton. The rock is a biotite granite of light-gray color and medium-fine grain. The principal minerals are potash and soda-lime feldspars, quartz, and biotite. The quarry had not been worked for some time prior to the writer's visit in July, 1908, and very little could be seen. The granite is reported to contain numerous knots of large and small size.

About a mile south of Winnsboro, immediately on the Winnsboro-Rockton highway, are exposures of a hornblende-bearing biotite granite of slightly pinkish medium-gray color and medium grain. Much titanite is visible in the hand specimens. This granite is the only one of those examined by the writer in the State in which hornblende is present. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and hornblende, together with accessory titanite, apatite, zircon, and iron oxide and secondary chlorite, kaolin, and light-colored mica. Plagioclase is in excess of potash feldspar. Intergrowths of feldspar (microperthite) and of feldspar and quartz (micropegmatite) are common. Irregular rounded inclosures of feldspar and quartz are contained in some of the larger feldspar individuals. Feldspar twinning on the Carlsbad law is shown.

GREENVILLE COUNTY.

The only granite quarried in Greenville County has been a small quantity obtained from the western slope of Paris Mountain, about 6 miles north of Greenville, the county seat, by the Paris Mountain Granite Company, of Greenville. The rock is a biotite granite of gray color, medium-fine grain, and indistinct gneissoid structure. The minerals are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, biotite, muscovite, and accessory apatite, titantite, and magnetite. Titanite is visible in hand specimens of the granite. Quartz and feldspar are locally intergrown in micropegmatitic structure. The granite apparently possesses good working qualities under the hammer and chisel. According to Sloan its specific gravity is 2.72 and its ratio of absorption 0.304.

A somewhat similar granite is exposed on the southern slope of Piny Mountain, about 2 miles northeast of Greenville, within 300 yards of the Atlanta and Charlotte division of the Southern Railway. This rock is a biotite granite of gray color, medium grain, and gneissoid structure. It has not been developed.

GREENWOOD COUNTY.

The *Benjamin quarry*, comprising a number of openings in bowlders and bowlder-ledge exposures grouped rather close together, is about 4 miles east-northeast of Greenwood and less than a mile north of Quarry station.

The rock is a biotite granite of medium-light pinkish-gray color and dense, medium-coarse grain. The feldspars in the hand specimens have a decided light-pink color. The minerals are potash feldspar (microcline and orthoclase, the latter partly microperthite), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory titanite, zircon, apatite, and iron oxide and secondary chlorite, epidote, and light-colored mica. The quartz contains threadlike inclusions of rutile. Microcline and oligoclase are the dominant feldspars. Much accessory titanite occurs. Small areas of micropegmatitic intergrowths of quartz and feldspar are shown.

A chemical analysis of the granite is given on page 174 (No. 9). The specific gravity is 2.65.

The sheets are from 4 to 8 feet thick, and the vertical joints are widely spaced. The decay is usually deep, necessitating at the two largest openings a stripping of several feet. The quarry had not been worked for some time prior to the writer's examination in July, 1908.

KERSHAW COUNTY.

Practically no quarrying of granite has been attempted in Kershaw County. Mica granites of excellent grade, possessing good working qualities and susceptible of a high polish, occur in the northwestern part of the county in the vicinity of Liberty Hill post-office.

About 7 miles southwest of Heath Springs and about 1½ miles southeast of the Excelsior granite quarry, in Lancaster County, are exposures of a biotite granite of medium-gray color and fine grain, similar to that quarried by the Southern Granite Company at the Excelsior quarry. The minerals are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, biotite, a little muscovite, together with accessory apatite and magnetite and secondary chlorite, kaolin, and iron oxide. Oligoclase and microcline are the dominant feldspars, the former showing considerable alteration, principally to kaolin. A chemical analysis of this granite, according to Sloan,[a] is given here for reference.

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[a] Sloan, Earle, op. cit., p. 219.

Analysis of granite 7 miles southwest of Heath Springs.

Silica (SiO_2)	72.22
Alumina (Al_2O_3)	14.51
Ferric oxide (Fe_2O_3)	1.28
Ferrous oxide (FeO)	1.52
Magnesia (MgO)	.58
Lime (CaO)	1.32
Soda (Na_2O)	3.21
Potash (K_2O)	4.30
Ignition	.52
Manganese oxide (MnO)	Trace.
Titanic oxide (TiO_2)	.24
Phosphoric oxide (P_2O_5)	Trace.
	99.70

The specific gravity is 2.63. This granite is uniform in color and texture, works well under the hammer and chisel, is susceptible of a high polish, and is one of the most desirable granites in the State for monumental purposes.

About half a mile north of Liberty Hill post-office, on the property of Mrs. Richards, is an outcrop of red-gray muscovite granite of medium-fine grain. Its principal minerals are oligoclase, orthoclase, microcline, quartz, muscovite, very little biotite, and accessory apatite. Soda-lime feldspar (oligoclase) is the principal feldspar and is considerably altered to kaolin.

The granite of Flatrock (old Dekalb granite), near Cleyburn, has been quarried to a moderate extent. It is a biotite granite of red-gray color and coarse-grained porphyritic texture. The principal minerals are orthoclase (partly microperthite), oligoclase, quartz, and biotite, with accessory apatite and magnetite. A chemical analysis of this granite is given on page 174 (No. 2). The specific gravity is 2.65.

LANCASTER COUNTY.

Two grades of granite occur in Lancaster County, but are limited principally to the southern part of the county, near the Kershaw County line. One is a biotite granite of dark-gray color and fine grain, and is used chiefly for monumental stock; the other is a biotite granite of coarse-grained porphyritic texture. Only the dark-gray fine-grained granite has been quarried to any great extent. Both are described below.

The *Excelsior quarry* of the Southern Granite Company, including two openings made in 1902, is located about 6 miles by rail (6½ miles by wagon road) southwest of Heath Springs, near the Kershaw County line. The rock is a biotite granite of dark blue-gray color and fine grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, colorless mica, and kaolin. The orthoclase is intergrown in part with plagioclase. Much microcline is present. Intergrowths of quartz and feldspar as micropegmatite occur. A chemical analysis of this granite, as reported by Sloan,[a] is given below.

Analysis of granite from Excelsior quarry.

Silica (SiO_2)	70.11
Alumina (Al_2O_3)	15.76
Ferric oxide (Fe_2O_3)	1.07
Ferrous oxide (FeO)	1.76
Magnesia (MgO)	.62
Lime (CaO)	1.84
Soda (Na_2O)	3.39
Potash (K_2O)	4.27
Ignition	.45
Manganese oxide (MnO)	Trace.
Titanic oxide (TiO_2)	.45
Phosphoric oxide (P_2O_3)	Trace.
Sulphuric oxide (SO_3)	Trace.
	99.72

The specific gravity is 2.66.

The main quarry opening is worked to a depth of 35 feet. Prior to its opening in 1902 many of the numerous large granite bowlders exposed over most of the tract of 1,093½ acres were quarried.

Vertical joints are few and widely spaced in the lower opening, which was being worked in July, 1908. They strike N. 3° W. and N. 80° W., and are sufficiently far apart to permit the quarrying of columns 25 to 60 feet long. Many 25-foot columns used in the construction of the president's house near the quarry were examined, and one 58 feet 5 inches long was loaded on the car at the time of the writer's visit. The joint faces are slickensided and coated with a whitish mineral substance, indicating some movement in the granite mass. Vertical joints in the abandoned opening on top of the knoll are rather numerous, striking N. 20° E., N. 10° W., and N. 45° W., and, as a rule, are closely spaced. Their faces are slickensided and coated with a reddish mineral substance. Here and there a pegmatite dike less than 1 inch thick is observed and there are a very few knots.

The granite is entirely uniform in color and texture, possesses good working qualities, is susceptible of a high polish, and is especially adapted to high-grade monumental stock, for which it is now used exclusively. The product has been shipped as far north as Brooklyn, N. Y., and west to Denver, Colo., and Portland, Oreg.

The quarry is connected with Heath Springs, on the Southern Railway, by a standard-gage railway track.

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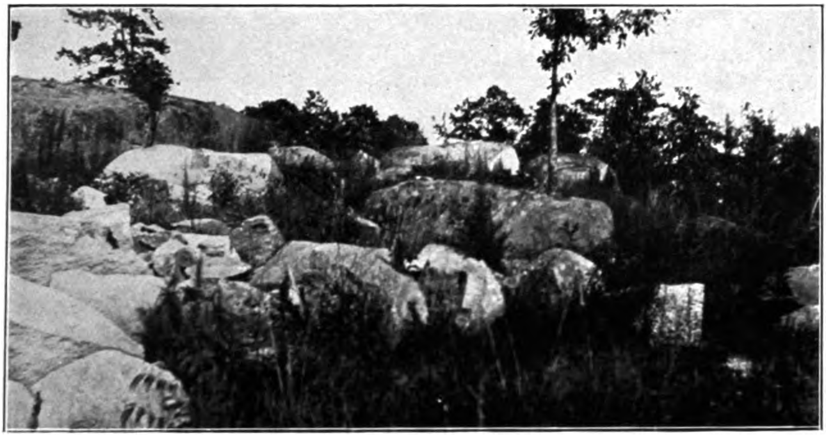
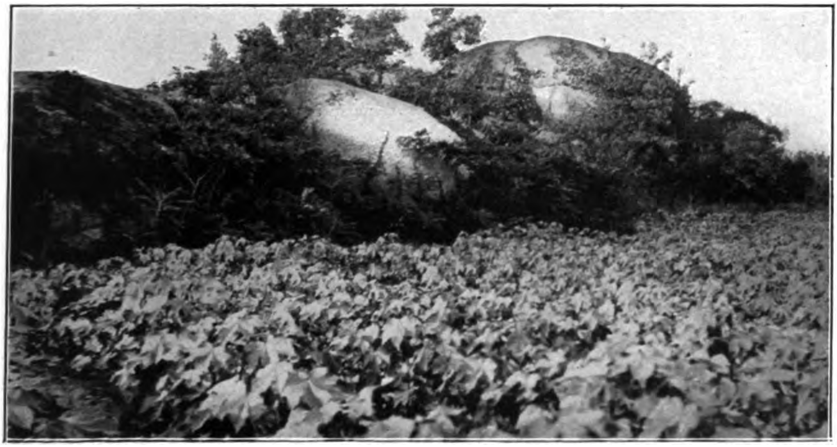
[a] Sloan, Earle, op. cit., p. 222.



A. BOWLDER OUTCROP OF GRAY GRANITE, RION QUARRY, FAIRFIELD COUNTY, S. C.



B. BOWLDER OUTCROP OF COARSE-GRAINED GRANITE 3 MILES SOUTHWEST OF HEATH SPRINGS, S. C.

C. BARED SLOPE OF GRANITE GNEISS, BEVERLY QUARRY, BEVERLY STATION, PICKENS COUNTY, S. C.

Beginning about 1½ miles southwest of Heath Springs and extending for a considerable distance along the highway to the Excelsior quarry is a coarse-grained porphyritic biotite granite of a mixed greenish-yellow and reddish-gray color, similar to that near Lilesville, Anson County, N. C., described on page 162. As shown in Plate XXIII, *B*, the granite is exposed in places in large bowlder outcrops. It has not been quarried, but its color and texture are such as to render it of value as a decorative stone. Its minerals are potash feldspar (orthoclase and microcline), much soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, a little colorless mica, and kaolin. The potash feldspar shows Carlsbad twinning. The plagioclase feldspar, which is equal to or greater in amount than the potash feldspar, is partly altered.

Sloan[a] has described porphyritic biotite granite of coarse grain from two other localities in Lancaster County—6½ miles west of Jefferson and 6½ miles northeast of Kershaw. The granite west of Jefferson is reported to have been used formerly for millstones.

LAURENS COUNTY.

Two grades of granite are quarried in Laurens County, one a fine-grained massive granite of light pinkish-gray color, the other a coarse-grained granite gneiss of medium dark-gray color. The granite is quarried at Cold Point station, south of Laurens, and the granite gneiss at Graycourt station, a little west of north from Laurens.

The *Cold Point Granite Company's quarry*, opened in 1904, comprises a principal opening and several smaller ones. It is located on the west side of the railroad less than half a mile north of Cold Point station. The rock is a biotite granite of light reddish-gray color and fine grain. The feldspar is of faint though marked reddish color. Biotite is present in small amount. The minerals are potash feldspar (orthoclase and microcline, the former largely microperthite), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, titanite, and zircon and secondary chlorite, epidote, and colorless mica. The orthoclase is intergrown with plagioclase. The larger feldspar individuals inclose irregular grains of quartz and feldspar.

According to Sloan[b] the absorption ratio of this granite is 0.344 and the specific gravity 2.65. A chemical analysis of the granite is given on page 174 (No. 3).

In the main quarry opening, worked to a depth of 40 feet, occurs an inclusion, 15 by 30 feet, of a thinly foliated dark (nearly black) gneiss. It is composed of dominant black lustrous biotite and some white feldspar and quartz and in places shows a partial porphyritic texture. The granite is sheeted in places near the surface but grades into massive rock at slight depth. The vertical joints strike N. 50° E. and N. 70° E. and are spaced at varying intervals. Some pegmatites and knots occur. From 4 to 6 feet of stripping is necessary in places. A No. 5 Austin crusher is operated at the quarry for crushing and sizing the stone. Blasting is employed for breaking down (quarrying) the rock. The product, in the form of crushed stone, blocks, and curbing, is used almost exclusively in the State.

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[a] Sloan, Earle, op. cit., pp. 224-225.

[b] Idem, p. 190.

The *Entrekin quarry* is located less than a mile east of Graycourt station. The rock is a biotite granite gneiss of medium dark-gray color and coarse grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite and zircon and secondary chlorite and epidote. Intergrowths of quartz and feldspar (micropegmatite) in small irregular areas are noted. There is considerable granulation of the quartz and feldspar, forming distinct areas of finer-grained mosaics. The quartz and feldspar further show strain effects in undulous extinction and fractures. The white feldspars, smoky vitreous quartz, and black lustrous biotite contrast strongly in the hand specimens. The resemblance of the granite gneiss from this quarry to that of the Beverly quarry (p. 197) is very striking. The minerals are segregated into alternating dark (dominant biotite) and light (dominant feldspar and quartz) bands, of irregular thickness and more or less contorted. Pegmatite dikes, quartz veins, and knots occur. The product is used principally for curbing, lintels, etc.

LEXINGTON COUNTY.

The granite quarries in Lexington County are near Columbia, in Richland County, and near Lexington, the county seat, 12 miles west of Columbia.

The *Ross quarry* is about 2 miles south of Columbia, on the opposite side of Congaree River from Morris & Co.'s (Lipscomb) quarry. The quarry is a large one, but at the time of examination, in July, 1908, it was idle and nearly filled with water. Preparations were then in progress for draining it preparatory to resuming operations for a contract to supply stone for government jetty work. The rock is a biotite granite of gray color and fine to coarse grain. Two facies of the granite are represented, similar to those at Morris & Co.'s quarry (p. 198). A chemical analysis of the granite is given on page 175 (No. 13). Its specific gravity is 2.68.

The *Casparis Stone Company's quarry*, opened about 1902, is located about 1½ miles N. 75° E. of Lexington station and about 300 yards north of the Columbia and Augusta division of the Southern Railway. The rock is a biotite granite of light reddish-gray color and medium grain, with a pronounced porphyritic tendency in places. The feldspars are pinkish and are in places elongated and flat tabular in outline. The granite from this quarry resembles that from the Smith Branch (County) quarry, near Columbia, except that it is of finer-grained texture. Its resemblance to the granite from the Bates quarry, in Saluda County, is also very striking. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and a little pyrite, with secondary chlorite, epidote, colorless mica, and kaolin. The feldspars show considerable alteration. Biotite is partly altered to chlorite. Intergrowths of the feldspars with each other (microperthite) and of the feldspars with quartz (micropegmatite) are indicated.

The quarry is of circular shape, about 200 feet in diameter and 50 feet deep. The vertical joints strike N. 5° to 10° E., N. 35° E., and N. 20° W.; several minor sets were not measured. They dip at various angles and are so closely spaced as to prevent the quarrying of dimension stone. The joint faces are slickensided and coated with a reddish mineral substance. An aplite dike 2 inches thick, of light-gray color and fine grain, was noted. Pegmatites and knots were not observed. From 1 foot to 5 feet of stripping is required.

The product is used chiefly in the form of crushed stone; in July, 1908, it was used foı government jetty work at Savannah, Ga. The quarry is connected with the Lexington station by a standard-gage track.

NEWBERRY COUNTY.

Extending north, northeast, and northwest from the town of Newberry is an extensive area of granite. The exposures are chiefly in the form of large and small bowlder masses, which have been worked in many places to supply the local demand for stone in buildings and monuments. No extensive quarries have been opened, the work done consisting in the quarrying of some of the larger bowlders, in places to considerable depth below the surface.

The three quarries described below are the most recently operated ones and are worked when a local demand for stone arises. Other similar openings of long standing have been made at several places in the Newberry granite area.

The *Leitzsey quarry*, opened in a bowlder exposure of granite, is about 5 miles northeast of Newberry. The rock is a biotite granite of medium-gray color and fine grain. Its minerals are potash feldspar (orthoclase, largely microperthite, and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and very little muscovite, together with accessory apatite, zircon, and magnetite and secondary chlorite, epidote, colorless mica, and kaolin. Orthoclase is intergrown with plagioclase as microperthite. Small roundish areas of quartz-feldspar intergrowths (micropegmatite) are common. A chemical analysis of this granite is given on page 174 (No. 5). Its specific gravity is 2.65.

The vertical joints strike N. 45° E. and N. 70° W., and are widely spaced. A few pegmatites, 1 to 2 inches thick, occur. The working qualities of the granite are good and it is susceptible of a very high polish. The product has been used extensively for monuments.

The *Spears* (*Baxter*) *quarry*, comprising two openings in large bowlder exposures of the granite, is about 4 miles northeast of Newberry. The rock is a biotite granite of medium-gray color and fine grain. The minerals are potash feldspar (orthoclase, chiefly microperthite and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with apatite, zircon, and magnetite and secondary chlorite, epidote, colorless mica, and kaolin. The orthoclase is intergrown with a second feldspar (plagioclase). Numerous small rounded areas of quartz-feldspar intergrowths (micropegmatite) occur. Some of the feldspar shows zonal structure· twinning on the Carlsbad law is noted.

The vertical joints are widely spaced. Several pegmatite dikes, a fraction of an inch to 1½ inches thick, occur. Knots were not observed. The granite works well under the hammer and chisel and is susceptible of a high polish. The product has been used locally in buildings and in monuments.

The *Level quarry*, opened in large bowlder exposures of granite, is about 3½ miles northwest of Newberry and about half a mile northwest of the Columbia, Newberry and Laurens Railway. An old opening of very long standing, filled with water at the time of examination in July, 1908, is near by. The rock is a biotite granite of medium-gray color and fine grain. Its minerals are potash feldspar (orthoclase, chiefly microperthite, and microcline), soda-lime plagioclase (oligoclase), quartz, and biotite, together with apatite and zircon and secondary chlorite, colorless mica, and kaolin. The orthoclase is intergrown with soda-lime feldspar. The oligoclase shows considerable alteration to a colorless mica and kaolin. Pegmatites and knots were not observed. The granite is susceptible of a high polish and works well under the hammer.

OCONEE COUNTY.

Gneisses which afford strong evidence of having been derived from original granites by metamorphic processes, chiefly granulation and recrystallization, are extensively distributed over parts of Oconee County. A quarry was opened in an exposure of the gneiss near the state line and stone was obtained for use as piers and abutments in the Southern Railway bridge over Tugaloo River.

At Tunnel Hill and Lays Mill, about 6 miles northwest and 7 miles northeast of Walhalla, respectively, are exposures of biotite gneiss of medium-gray color and fine grain. The porphyritic texture is usually distinct, imparting an augen effect to the gneiss; the porphyritic mineral is pink microcline. Muscovite is usually present, associated with the biotite. These minerals show marked orientation, to which is due the banding of the gneiss. Thin sections of the rocks from these localities indicate derivation from porphyritic granites, chiefly by granulation and recrystallization.

PICKENS COUNTY.

The *Beverly quarry*, operated in 1908 by the Greenville Crushed Stone Company, is located at Beverly station, on the northwest side of the Atlanta and Charlotte division of the Southern Railway. The railroad extends along the southeastern base of the doming ridge in which the quarry is opened. The rock is a contorted biotite granite gneiss of medium to dark gray color and medium grain. It consists of white potash feldspar (orthoclase and microcline), white soda-lime feldspar (oligoclase), clear or barely smoky quartz, black mica (biotite), and a little white mica (muscovite), together with accessory titanite, zircon, apatite, and iron oxide and secondary chlorite, epidote, and colorless mica. Orthoclase is partly intergrown with a second feldspar as microperthite. Microcline shows evidence of having been derived in part from orthoclase. Micropegmatite intergrowths as small areas are indicated, and some of the larger feldspar individuals show micropoikilitic structure (inclosures of rounded quartz chiefly). Granulation of the quartz and feldspar is pronounced and orientation of the biotite is usually well marked. In the hand specimens much titanite is visible in association with the biotite. Here and there pyrite is noted.

The following analysis of granite gneiss from the Beverly quarry, quoted from Sloan's report,[a] will indicate the general chemical composition of the rock:

Analysis of granite gneiss from the Beverly quarry.

Silica (SiO_2)	68.15
Alumina (Al_2O_3)	14.30
Ferric oxide (Fe_2O_3)	2.44
Ferrous oxide (FeO)	2.49
Magnesia (MgO)	1.04
Lime (CaO)	2.80
Soda (Na_2O)	3.80
Potash (K_2O)	3.84
Ignition	.28
Titanic oxide (TiO_2)	.60
Manganese oxide (MnO)	.11
Phosphoric oxide (P_2O_5)	Trace.
Sulphur oxide (SO_3)	Trace.
	99.85

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[a] Sloan, Earle, Bull. South Carolina Geol. Survey, ser. 4, No. 2, 1908, p. 181.

The specific gravity is 2.66. Sloan gives the absorption ratio as 0.398.

The quarry was opened about 1894 and is approximately 300 by 405 feet, with a vertical face of 80 feet, the greatest depth of working. Sheeting does not occur and pegmatites and knots have very scanty development, only a few small ones being observed. There is no stripping. (See Pl. XXIII, *C.*)

The vertical joints are widely spaced. The principal set trends N. 60° E. with dips of N. 50° E. and N. 58° W. Slickensides are developed on the joint faces, and are coated locally with a yellowish mineral substance, indicating movement in the granite mass since the formation of the joints.

The rock is composed of alternating more or less continuous dark (dominant biotite) and light (dominant feldspar and quartz) bands of variable thickness and highly contorted. As a rule the dark bands are much thinner and less continuous than the light ones. A marked tendency toward porphyritic texture is observed in places, imparting to the rock somewhat the appearance of an augen gneiss. The granite gneiss from the Beverly quarry closely resembles a similar granite gneiss quarried at Lithonia (p. 253) and Odessadale (p. 262), Ga., and Rocky Face Mountain (p. 152), Alexander County, N. C. The Beverly rock is coarser grained than that of the Georgia localities.

This quarry, located directly on the railroad, possesses excellent advantages for operating. The entire product is crushed at the quarry and is used principally for concrete work and roofing gravel.

RICHLAND COUNTY.

The granite quarries in Richland County lie near the city of Columbia, on the south and northwest sides. The granites are mostly concealed beneath a thin cover of the Coastal Plain gravel, sand, and clay, and in position are very similar to those of areas in North Carolina, Virginia, and Maryland on the north and in Georgia on the south.

The *Morris & Co.* (*Lipscomb*) *quarry*, opened about 1883, is located about 1½ miles south of Columbia, on the east side of and near Congaree River. Two facies of the granite, which usually grade into each other without sharp definition, occur in the quarry. The dominant one is a biotite granite of medium-gray color and medium-coarse grain, with a pronounced porphyritic tendency in places. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, light-colored mica, and kaolin. A part of the feldspar is twinned on the Carlsbad law. Some of the larger feldspar individuals inclose irregular rounded grains of quartz and feldspar. Micropegmatite areas are numerous.

The second facies is a biotite granite of medium dark-gray color and fine grain. Here and there porphyritic feldspar is conspicuously developed and twinned on the Carlsbad law. The minerals are the same as in the dominant facies just described. Carlsbad twinning and micropoikilitic and micropegmatitic structures are common.

The quarry is a large one, measuring approximately 750 by 500 feet and 50 to 75 feet deep. The sheets, 6 inches to 4 feet thick, are horizontal and grade into massive granite with increasing depth. The vertical joints strike north-south, N. 70° E., N. 10° W., and N. 50° W., and as a rule are spaced at intervals of 2 to 4 feet. The joint faces are slickensided, being coated with a reddish to greenish-yellow mineral substance. Pegmatite dikes, from a fraction of an inch to 6 inches thick, are common. The feldspar of the pegmatite dikes is white; biotite is present, though very subordinate in amount. Knots occur but rarely.

The granite is of good quality and is suitable for a wide range of uses. It has had an extensive use in government jetty work. The entire product at present goes into crushed stone, the average production of which during the summer of 1908 was between 4,000 and 5,000 tons a month. A large crushing plant is operated at the quarry.

The *Smith Branch* (*County*) *quarry* is located on the north side of Smith Branch, about 300 yards west of the Seaboard Air Line Railway and about 2 miles N. 25° W. of Columbia. The rock is a biotite granite of mixed reddish-gray color and coarse grain. The feldspars are of a pronounced pinkish color and much of the quartz is of the dark smoky variety. Both of these minerals are larger in size than the biotite. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite and magnetite and secondary chlorite, epidote, colorless mica, and kaolin. The soda-lime feldspar is equal to or greater than the potash feldspar. Twinning on the Carlsbad law is noted.

The quarry is roughly circular in shape, measuring approximately 50 by 60 feet and 40 feet deep. The decayed granite extends to a depth of 10 to 15 feet. The vertical joints strike N. 60° E., dip about 50° NW., and are widely spaced. The joint faces are slickensided, being coated with a yellowish mineral substance. Brownish-red aplite dikes of exceedingly dense, fine-grained texture, without visible mica, are rather abundant. The largest one, a dike 4 feet thick, strikes northeast and dips to the southeast. The mineral composition is identical with that of the inclosing granite—orthoclase, a little microcline, much oligoclase, quartz, a little biotite, accessory apatite, and secondary chlorite and epidote. The potash feldspar is apparently in excess of the soda-lime feldspar.

SALUDA COUNTY.

The only granite area in Saluda County in which quarries have been opened is in the extreme southeast corner of the county, near the Lexington County line, extending northward from a point half a mile north of Batesburg to and beyond Clouds Creek, a distance of 5½ miles. In this area are large exposures of granite, chiefly in bowlder and flat-surfaced masses. Variation in texture, color, and structure is observed. A decided porphyritic tendency is very generally shown. No systematic quarrying has been attempted in this area, the openings are small, and the consumption of the product is local.

The *Bates quarry* includes numerous small openings widely separated, located from half a mile to a mile north of Batesburg. The rock is a biotite granite of pinkish-gray color and medium to coarse grain. The feldspars are of larger size than the other components and impart a porphyritic appearance to the rock. They are of irregular outline and are partly pink in color. A partial parallel arrangement of the biotite is discernible in places and the granite shows an indistinct foliation. The minerals are potash feldspar (orthoclase chiefly and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, mica, and kaolin. Abundant quartz-feldspar intergrowths (micropegmatite) occur. A partial peripheral granulation of the quartz and feldspar is shown and a rude orientation of the biotite is noticeable.

In one opening the rock is a typical granite gneiss of gray color and fine grain. It is identical in mineral composition with the granite, except that some muscovite is present. A chemical analysis of the gneiss is given on page 175 (No. 19). The specific gravity is 2.64.

The *Whittle quarry* includes several small openings on the south side of Moores Creek, about 4 miles northwest of Batesburg. The rock is a porphyritic biotite granite of dark-gray color and coarse grain. The quartz has a decided bluish opalescent cast and the groundmass feldspars are dark gray. As a rule the feldspar phenocrysts are of irregular outline, roughly rounded, the largest measuring about 2½ by 1¾ inches. They inclose biotite and are of white to gray color. The minerals are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, and biotite, with secondary colorless mica, chlorite, iron oxide, and kaolin. The feldspar and biotite show some alteration, the former to mica and kaolin, the latter to chlorite and iron oxide. The orthoclase is partly intergrown with plagioclase. Carlsbad twins are common. The feldspar and quartz are crossed by fractures which are filled with mineral matter.

A chemical analysis of a similar granite on Milton Prater's place on Clouds Creek, 4.7 miles north of Batesburg, taken from Sloan's report,[a] is given below and serves to show the general composition of the rock.

Analysis of porphyritic granite from Prater's place, north of Batesburg, S. C.

Silica (SiO_2)	68.70
Alumina (Al_2O_3)	15.49
Ferric oxide (Fe_2O_3)	1.10
Ferrous oxide (FeO)	3.73
Magnesia (MgO)	.86
Lime (CaO)	1.70
Soda (Na_2O)	3.09
Potash (K_2O)	3.36
Ignition	.81
Manganese oxide (MnO)	Trace.
Titanic oxide (TiO_2)	.84
Phosphoric oxide (P_2O_5)	Trace.
Sulphuric oxide (SO_3)	.13
	99.51

The specific gravity is 2.73.

The dark-gray, coarse-grained porphyritic granite occupies an extensive area, the width of which is not less than 3 miles. Large bowlder outcrops are abundant near Moores and Clouds creeks. Numerous small openings have been made in the vicinity of both streams and some of these date back many years. The product was formerly used for millstones.

SPARTANBURG COUNTY.

The quarries in Spartanburg County are near Pacolet, about 12 miles southeast of the city of Spartanburg.

The *Pacolet Granite Company's* (*Johnson*) *quarry* is located about 0.75 mile northwest of Pacolet station. The dominant facies of the rock is a biotite granite of medium-gray color and fine grain. A second facies is a pronounced biotite granite gneiss of light-gray color and fine grain. The banding of the gneissic phase is in places highly contorted. Mineralogically there is no difference in the two facies. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and a little muscovite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, much epidote, light mica, and kaolin. The orthoclase is intergrown with plagioclase as microperthite. The feldspars are partly altered to kaolin and light mica. A partial granulation of the quartz and feldspar is apparent in small areas of fine-grained mosaics. Some of the larger feldspar individuals inclose irregular rounded grains of quartz and feldspar.

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[a] Sloan, Earle, op. cit., p. 192.

The quarry had not been worked for some time prior to the writer's visit in July, 1908. It is roughly circular in outline, about 250 by 300 feet and 15 to 20 feet deep. The sheets range from 4 inches to 2 feet in thickness and are approximately horizontal. The vertical joints strike east and west and are spaced at intervals of 1 inch to 3 feet. The faces of some of the joints are slickensided. Pegmatite dikes up to 12 inches thick are abundant. Besides the usual minerals—feldspar, quartz, and mica (biotite and muscovite)—some of the pegmatite dikes carry black tourmaline. There are some knots in the granite. Several feet of stripping is necessary.

The *Keystone Granite Company's quarry,* comprising two openings half a mile apart, is 2½ miles N. 20° W. from Pacolet station. The rock is a biotite granite of medium-gray color and fine grain. It is identical with the dominant facies of granite at the Pacolet Granite Company's quarry, described above. The minerals are potash feldspar (orthoclase and a little microcline), soda-lime feldspar (oligoclase), quartz, biotite, and some muscovite, together with accessory apatite, zircon, and magnetite and secondary chlorite, epidote, kaolin, and much light-colored mica. The orthoclase is partly intergrown with plagioclase as microperthite. Twinning on the Carlsbad law occurs. Rutile is present as threadlike inclusions in the quartz. Some of the feldspar shows partial alteration into kaolin and light-colored mica.

A chemical analysis of the granite made by the Pittsburg Testing Laboratory, Pittsburg, Pa., is given on page 175 (No. 12). Sloan[a] gives the compressive or crushing strength as 21,420 pounds to the square inch.

The largest opening is about 300 by 350 feet and 30 feet deep. The sheets average several feet in thickness. The vertical joints strike east and west and are widely spaced; their faces are locally slickensided. Pegmatite dikes up to 18 inches thick are observed. A large cutting and polishing plant was formerly operated at the quarry, but it has been almost dismantled. A spur track, now unused, runs between the quarry and Pacolet station.

The working qualities of this granite are very good. It is susceptible of a high degree of polish and of carved work, as shown in large pieces of the granite at the old dressing plant. It was extensively used for monumental stock.

UNION COUNTY.

Granite has been quarried at two localities in Union County—in the extreme southeast corner, northwest of Carlisle, and near the center, within several miles on the south and west sides of Union, the county seat. The product from the quarries near Union was used for macadamizing the streets of Union and the county highways. The granite formerly quarried northwest of Carlisle merits description.

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[a] Sloan, Earle, op. cit., p. 198.

Flatrock quarry is about 2½ miles north-northwest of Carlisle. It consists of one fairly large opening last worked about fourteen years ago. The rock is a biotite granite of medium-gray color and fine grain, both color and texture being very uniform. The feldspars are white and highly lustrous. The minerals are potash feldspar (orthoclase, partly microperthite, and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and a few shreds of muscovite, together with accessory apatite, zircon, and magnetite and secondary chlorite, epidote, and light-colored mica. A part of the feldspar is considerably altered. Zonal and micropoikilitic structures and Carlsbad twinning are indicated in some of the feldspars. Micropegmatite (intergrowths of quartz and feldspar) occurs in small, irregularly rounded areas.

A chemical analysis of this granite is given on page 174 (No. 8). The specific gravity is 2.63.

There are several sets of vertical joints having directions of N. 30° E., N. 35° W., N. 60° W., N. 70° W., and east-west. Slickensides are developed on some of the joint faces. There are a few small knots and pegmatites.

The product from this quarry was used for bridge piers along the Seaboard Air Line Railway and to some extent in the neighborhood for buildings.

YORK COUNTY.

The granites of York County which have thus far attracted attention and are of economic importance are limited to the north-central portion of the county. Beginning near Bowling Green, at the state line on the north, the area extends southward to Yorkville and probably beyond and is traversed in a nearly north-south direction by the Yorkville-Gastonia Railway. The granites are biotite granites, but vary in color and texture, as indicated in the individual descriptions of the two areas below. Systematic quarrying has not been attempted, but a little stone has been quarried from time to time in different places to meet the local demand.

Clover area.—The Clover area, containing a single type of biotite granite, extends southward from a point near Bowling Green to Yorkville. The granite is exposed at the surface in many places over the area in nearly flat-lying (locally called "flat-rock") and sloping surface masses of considerable areal extent. Exposures of this character are especially noted within a radius of 2 miles to the north, northwest, east, and southeast of Clover station. The exposures of the granite near Filbert station (west side) are in the form of huge isolated bowlders 10 to 15 feet high and proportionately large otherwise. A small amount of the granite has been quarried from surface "raises" at a number of places in the vicinity of Clover.

The rock is a biotite granite of light-gray color and medium-coarse, even-granular to porphyritic texture. Both feldspar and biotite show some alteration in the surface portions of the granite, the former appearing white, opaque, and chalky from partial kaolinization, the latter showing irregular areas of reddish-brown staining from partial leaching of the iron oxide immediately adjacent. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and occasional muscovite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, colorless mica, and kaolin. Intergrowths of orthoclase with plagioclase feldspar, as microperthite, and of feldspar with quartz, as micropegmatite, are abundant. The larger feldspar individuals carry many inclosures of feldspar, chiefly quartz and feldspar-quartz intergrowths (micropegmatite). Microcline exceeds orthoclase in some sections and is much less in others. Plagioclase, likewise, may be greater or less in amount than potash feldspar. The feldspars are in part much altered and some of them show peripheral granulation from pressure effects.

In the porphyritic facies of this granite the feldspar phenocrysts are of both regular (idiomorphic) and irregular (allotriomorphic) outline and of white color and contain inclosures of groundmass biotite. In size they range up to 2 inches by half an inch. The ratio of phenocrysts to groundmass is very variable.

A chemical analysis of the granite from Jackson's quarry, half a mile north of Clover, reported by Sloan,[a] is given below and shows the general composition of the rock in the York County area. The specific gravity is 2.66.

Analysis of granite from the Jackson quarry, York County.

Silica (SiO_2)	68.90
Alumina (Al_2O_3)	15.75
Ferric oxide (Fe_2O_3)	1.16
Ferrous oxide (FeO)	1.49
Magnesia (MgO)	.74
Lime (CaO)	2.66
Soda (Na_2O)	4.76
Potash (K_2O)	3.49
Ignition	.18
Manganese oxide (MnO)	Trace.
Titanic oxide (TiO_2)	.36
Phosphoric oxide (P_2O_5)	Trace.
Sulphuric oxide (SO_3)	Trace.
	99.49

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[a] Sloan, Earle, op. cit., p. 216.

Filbert area.—The Filbert area lies several miles west of Filbert station. The granite quarried on the Whiteside place, on Buckhorn Creek, 2 miles west of Filbert, may be taken as the type. It is a biotite granite of medium-gray color and fine grain, with a pronounced porphyritic tendency in places. The scattered feldspar phenocrysts are usually of irregular (allotriomorphic) outline, locally flat-tabular (idiomorphic), measuring up to 1 inch by half an inch, and twinned on the Carlsbad law. They are of white color. The minerals composing the granite at the Whiteside quarry are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and scant muscovite, together with accessory apatite and zircon and secondary chlorite, epidote, and light mica. Feldspar intergrowths as microperthite and feldspar-quartz intergrowths as micropegmatite are abundant.

A chemical analysis of this granite is given on page 174 (No. 10). The specific gravity is 2.65.

The sheets are from 6 inches to 2 feet thick and the vertical joints recur at wide intervals. There are a few pegmatite dikes not exceeding 2 inches in thickness and some scattered small knots.

Quarrying operations were suspended in the spring of 1908. The product was used for building purposes in Yorkville.

CHAPTER VII.

THE GRANITES OF GEORGIA.

THE GEORGIA PIEDMONT REGION.[a]

TOPOGRAPHY.

The Georgia Piedmont region occupies the middle northern portion of the State. It is a belt of undulating country having a northeast-southwest extension along the eastern base of the Appalachian Mountains and disappearing beneath the Coastal Plain sediments on the southeast. It has an altitude along its western edge of about 1,000 feet and slopes gradually seaward, with an elevation along the fall line, its southeastern limit, of 250 to 300 feet. Residual masses of partly reduced areas, such as Kenesaw, Lost, and Stone mountains, rise several hundred feet above the general level of the upland surface.

The major streams preserve a general parallelism in their courses across the Piedmont region. With the exception of the upper course of Chattahoochee River, the major streams trend in general to the southeast, approximately at right angles to the northeast-southwest course of the plateau. The streams have apparently maintained their courses across the plateau regardless of the structure and hardness of the rocks. They have cut through the deep mantle of decayed rock into the fresh, hard rock beneath. The resulting valleys are deep and narrow, and the interstream areas are as a rule marked by low, rounded hills and ridges of slight and gentle curvature.

All the large streams except Savannah and Chattahoochee rivers head within the limits of the plateau. The Chattahoochee rises near the South Carolina line and flows across the plateau in a nearly southwest course, changes to a southward course near the middle southern portion of the plateau, at the Alabama line, and continues so to the Gulf. This stream presents an unsymmetrical aspect with reference to its tributaries.[b] Since the establishment of the minor drainage ways on the plateau some of them, by means of more favorable conditions, have encroached on the northeast drainage area of the Chattahoochee. A strong southeast slope has been acquired by the plateau since its elevation in middle Mesozoic time, which has enabled the minor drainage lines to establish straight and regular courses at right angles to that of the Chattahoochee, while forming in the basins of the other major streams a symmetrical drainage of dendritic pattern.

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[a] Watson, T. L., Bull. Geol. Survey Georgia, No. 9-A, 1902, pp. 60-65.

[b] Campbell, M. R., Drainage modifications and their interpretation: Jour. Geology, vol. 4, 1896, pp. 672-673.

The western portion of the plateau in the vicinity of Cartersville lies wholly within the drainage basin of the Etowah. The conditions in the Georgia Piedmont are similar to those in the same province through the Carolinas, Virginia, and Maryland; the streams are not navigable within the limits of the area, a fact which precludes the shipment of stone by water.

GEOLOGY.

ROCKS OF THE PLATEAU.

The Piedmont region is composed of crystalline rocks, which in places afford at present but little evidence of having been deposited as sediments. Whatever may have been their origin, they have been subjected to such profound metamorphism, mainly pressure and recrystallization, that proof of sedimentation is scant. This metamorphism has induced a secondary foliation in the rocks, by arranging the mineral constituents along parallel lines that evidently bear little or no relation to the possible original bedding planes in many of the sedimentary rocks.

The rocks consist principally of granites, gneisses, and schists, invaded by dikes of basic eruptive rocks belonging mainly to the gabbroic, dioritic, and diabasic types. Along the northwestern margin and in other parts of the plateau a belt of basic ferromagnesian silicate rocks, containing deposits of corundum, crosses the State in an approximately northeast-southwest direction. In the eastern, middle, northern, and southwestern parts of the plateau are belts of quartzite and in some places limestone. The rocks usually dip to the southeast at variable angles, and strike from 20° to 30° east of north. Local variations in both dip and strike are shown in all parts of the region.

AGE RELATIONS OF THE ROCKS.

Very little has yet been done toward deciphering the age and structural relations of the rocks of the Georgia Piedmont region. According to Hayes[a] the southeastern portion of Bartow County in northwestern Georgia is about equally divided between the older crystalline and metamorphic rocks of the Piedmont Plateau and Appalachian Mountains on the east and the Paleozoic sediments of the Appalachian Valley on the west. The Paleozoic sediments are

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[a] Hayes, C. W., Geological relations of the iron ores in the Cartersville district, Georgia: Trans. Am. Inst. Min. Eng., vol. 30, 1901, pp. 403-408.

Cambrian to Silurian in age. To the south and east of them lie the metamorphic crystalline rocks of the Piedmont area, comprising slates, schists, conglomerates, gneiss, and granite. The oldest of these rocks is the granite at Corbin, Ga., which is mapped as pre-Cambrian. The conglomerate, slate, and schist were mapped as Ocoee and provisionally assigned to the Algonkian because no fossils were found in the rocks and because they have every appearance of extreme age.

The rocks of the Ocoee group generally show an increasing degree of metamorphism toward the southeast; within a few miles of this region they pass into schists and gneisses, the original form of which, whether igneous or sedimentary, can not be determined. This increased metamorphism toward the southeast is due in part to the greater compression which that region has suffered and in part to the intrusion of considerable bodies of igneous rocks into the sedimentary beds.

The intrusive rocks present a considerable variety in composition, varying from extremely basic diabase to acidic granite. Diorite is the most common type and was among the earlier intrusions. It has been metamorphosed for the most part into amphibolite schist. An area near Acworth, Ga., is occupied by gneiss which, like the granite at Corbin, is probably Archean in age and formed the foundation on which the oldest sediments of the region were deposited.

Several thin bands of magnesian limestone and larger areas of sandstone or quartzite occur in the Georgia Piedmont area, intimately associated with other probably older metamorphic crystalline rocks. It is not unlikely that careful study will reveal a post-Algonkian age for at least the limestones and the quartzite of this area.

In his study of the granites and gneisses of the Georgia Piedmont region,[a] the present writer mapped and described most of them as pre-Cambrian. Several periods of intrusion of closely similar acidic material are represented, the earliest being schistose in structure, the later massive. The granite gneisses, regarded as belonging to the earlier intrusion, are pre-Cambrian, and the massive granites representing the later period of intrusion are very probably Paleozoic in age.

THE GRANITES.

FIELD RELATIONS.

The Piedmont region in Georgia is occupied chiefly by mica schists and gneisses, cut in places by dikes of basic eruptive rocks. The schist-gneiss complex is invaded by large masses of granite. From many of the larger granite masses well-defined granite dikes or tongues project and cut abruptly into the adjacent rocks. The line of contact between the granites and the contiguous fresh rocks can be observed in few places, because of the extreme depth of residual decayed material, but here and there the contact is shown in the partial decay of the rocks and the relations of the granites to the surrounding schists are apparent.

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[a] Watson, T. L., Granites and gneisses of Georgia: Bull. Geol. Survey Georgia, No. 9-A, 1902, 367 pp.

Mica-quartz schist forms a considerable part of the crystalline complex. It is a thinly foliated rock with somewhat variable mineral composition, ranging from a rock containing dominant quartz to one containing dominant mica. Feldspar is in many places nearly or entirely absent, but locally it forms an important constituent. Fresh exposures of this rock are rare in the Georgia area.

The dikes of basic eruptive rocks are less common in the Georgia granites than in those of North Carolina. They vary from a few inches to a few hundred feet in width and some of them can be traced for many miles on the surface. They present the usual characteristics of gabbros, diabases, and diorites, and range from gray to almost black in color. In mineral composition they vary from olivine-free rocks to those in which olivine is an important constituent, and in texture from fine to coarse granular. The final product of weathering of the basic eruptive rocks is a stiff, highly ferruginous deep-red to yellow clay.

No definitely identified inclusions of foreign rocks have been observed in the exposed granite masses, but many of the granites contain areas of an irregular character, which can doubtless be ascribed to such origin. In some respects these bodies differ strongly from the inclosing granites and many of them probably represent inclusions of foreign rock. Basic segregations (schlieren) of various sizes and shapes, such as form so common a feature of slowly solidifying granite magmas, are present in many of the granite stocks. They are abundant in the porphyritic granite area of Fayette County and in the granite worked by the Greenville Granite Company in Meriwether County. The segregations are darker in color and finer grained in texture than the inclosing granites, are more or less rounded in outline, and in places display a decided porphyritic tendency. Irregular dark bodies of variable size, composed almost entirely of biotite, are common in some of the Lithonia quarries.

DISTRIBUTION.

The granites and granite gneisses of workable grade in Georgia are limited to the Piedmont region, described on pages 217-267. That the granitic rocks are very generally distributed over the Georgia crystalline area is indicated by the fact that of the sixty-one counties composing the area, few, if any, are without such rocks. The quarrying industry, however, is confined to ten of the sixty-one, and, in fact, the total output of quarried granite shipped beyond the limits of the State comes from only four counties, of which Dekalb County is vastly the largest producer.

The map (Pl. XXIV) shows the distribution of the granites and gneisses that are quarried in Georgia. They occur in five principal areas—(1) the Elberton-Oglesby-Lexington area, (2) the Lithonia-Conyers-Lawrenceville area, (3) the Fairburn-Newnan-Greenville area, (4) the Stone Mountain area, and (5) the Sparta area. The most important of these at present, commercially, are the Lithonia and Stone Mountain areas, in Dekalb County, the stone from which is used principally for building and street purposes and is not desirable for monumental stock. For the latter purpose the stone from the Oglesby-Lexington area is the most desirable in the State. Besides the five principal areas named above, there are numerous minor ones in which more or less stone has been quarried at times for strictly local purposes.

GENERAL CHARACTER OF OUTCROPS.

The Georgia granites are exposed at the surface in the form of large horizontal masses, as dome-shaped areas of steep and gentle slopes, as large well-rounded bowlders scattered over the surface and partly buried in the residual clay, and as ledges exposed along the streams. The outcrops of the horizontal masses vary in extent from 1 acre to 50 acres or more; the dome-shaped areas contain from 50 to many hundred acres of exposed rock.

The best illustrations of the horizontal masses occur in Hancock, Heard, Meriwether, and Pike counties. Stone Mountain, in Dekalb County, which rises to an elevation of 686 feet above the surrounding lowland plain and has a basal circumference of approximately 7 miles, is the most extensive of the dome-shaped masses. Pine, Arabia, Collinsville, McDaniel, and Rock Chapel mountains, belonging to the Lithonia-Conyers-Lawrenceville area of contorted granite gneiss, are some of the other dome-shaped areas which vary in elevation from 75 to 200 feet. Similar exposures of porphyritic granites include the Heggie (Cedar rock) area in Columbia County and the porphyritic area 10 miles south of Greensboro, in Greene County. Outcrops of the kinds described above are numerous throughout the Georgia Piedmont region.

The large exposures require no stripping prior to opening quarries, but in many of the smaller areas, if extensive quarrying is contemplated, it is necessary to remove a variable depth, up to 12 feet or more, of loose residual material before hard rock can be reached. For a slight depth below the surface the bared and hard rock surfaces in the natural outcrops invariably show a partial decay and discoloration termed "sap," which must be removed before fresh rock can be quarried. The first or surface "raise" usually removes all the sap portion of the rock so that the second and succeeding raises include fresh granite.

CHEMICAL COMPOSITION.

The Georgia granites show more or less variation in texture and structure and are grouped accordingly as even-granular granites, porphyritic granites, and granite gneisses. In chemical composition the three groups show remarkably close agreement and are similar to the granites from the other States described in this bulletin. The analyses of the Georgia granites show their most characteristic feature to be a high soda content, which is above the average for normal granites. The soda and potash show nearly equal percentages in most of the analyses, but in some the potash exceeds the soda and in others the soda is in considerable excess over the potash. The high soda content is due principally to the presence of large amounts of plagioclase feldspar, which places the rocks with the quartz monzonites. Analyses were made of the potash feldspar phenocrysts from two of the widely separated porphyritic areas, with the result that approximately one-third of the potassium was found to have been replaced by sodium in the orthoclase (analyses 4 and 5 below).

Analyses of Georgia granites.[a]

Constituents.	1.	2.	3.	4.	5.
Silica (SiO_2)	69.67	69.28	73.76	64.64	64.40
Alumina (Al_2O_3)	16.63	16.73	14.52	19.64	18.97
Iron oxide (Fe_2O_3)	1.28	1.75	1.03	.37	.37
Magnesia (MgO)	.55	.72	.29	Trace.	Trace.
Lime (CaO)	2.13	2.16	1.14	.67	.59
Soda (Na_2O)	4.73	4.33	4.16	3.06	3.60
Potash (K_2O)	4.71	4.59	4.63	10.00	11.40

[a] Watson, T. L., Granites and gneisses of Georgia: Bull. Geol. Survey Georgia No. 9–A, 1902, pp. 239, 241.

1. Average of 21 analyses of Georgia even-granular granites.
2. Average of 10 analyses of Georgia porphyritic granites.
3. Average of 12 analyses of Georgia granite gneisses.
4. Porphyritic feldspars (phenocrysts) from Heggie Rock, Columbia County, Ga.
5. Porphyritic feldspars (phenocrysts) from McCollum place, Coweta County, Ga.

Averages of 21, 10, and 12 analyses of the even-granular granites, porphyritic granites, and granite gneisses, respectively (1, 2, and 3 in the table), show remarkable uniformity in the soda and potash contents for these groups of granite rocks; but many of the individual analyses exhibit a greater variation. The high range in total alkalies (Na_2O+K_2O) is also a very noteworthy feature in these analyses. The general average for the total alkalies is from 8.79 per cent in the granite gneisses to 9.44 per cent in the granites.

The Georgia granites contain an average of approximately 70 per cent of silica, as shown in the table. The normal granites and their porphyritic facies show no appreciable difference in silica content, as would be expected; but the granite gneisses are slightly more acidic and range from 3 to 4 per cent higher in this constituent. This relationship in the silica content is almost equally well shown when a comparison of individual analyses of the several groups is made.

MINERAL COMPOSITION.

The close similarity in mineral composition between the three types of granitic rocks here distinguished can not be emphasized too strongly. They are as nearly identical in mineral composition as different rocks could well be. The minerals found in one are invariably present in the others, and those most abundant in one also predominate in the others.

The granitic rocks of Georgia are made up of mixtures of the essential minerals feldspar, quartz, and biotite, with varying proportions of muscovite intimately associated with the biotite. Plagioclase is invariably present in large amount and in many rocks exceeds the orthoclase. Biotite is subordinated to muscovite in only two of the specimens examined. The absence of hornblende is a marked feature. Other minerals that are common to most granites occur as microscopic accessories, but do not exert any influence on the properties of the rock. A number of other minerals, such as calcite, garnet, tourmaline, hornblende, hyalite, molybdenite, and uranophane, occur sporadically in several localities, but are only of local interest.

PHYSICAL TESTS.

The following table gives some properties of the even-granular granites of Georgia:

Properties of Georgia even-granular granites.

Quarry.	Specific gravity.	Ratio of absorption.	Weight per cubic foot (pounds).	Cubic feet of stone in 2,000 pounds.
Lexington Blue Granite Co	2.666	0.092	166.25	12.0
Diamond Blue Granite Co	2.666	.088	166.62	12.0
Echols Mill	2.657		166.06	12.0
Sam Hill	2.689		168.06	11.9
R. D. Cole	2.700		168.75	11.8
A. M. Hill	2.731		170.68	11.7
T. B. Tigner	2.739		171.18	11.6
Greenville Granite Co	2.662	.086	166.37	12.0
Swift & Wilcox	2.652	.090	165.75	12.0
Swift & Wilcox "flat rock"	2.645	.092	165.31	12.0
Tate & Oliver	2.670	.093	166.87	11.9
Coggins	2.840	.090	177.50	10.7
Bisson	2.664		166.50	12.0
Deadwyler (Collins & Venable)	2.662		166.37	12.0
Childs	2.665	.092	166.56	12.0
Carmichael	2.658		166.12	12.0
Linch	2.701	.060	168.81	11.8
Stone Mountain	2.686	.067	167.90	11.9

The following table shows the results of tests on specimens of granite from Stone Mountain and contorted granite gneiss from Lithonia, Ga.:

Crushing tests of Georgia even-granular granite and granite gneiss.[a]

AT WASHINGTON NAVY-YARD, 1887.

Locality.	Dimensions (inches).	Crushed at—	
		Pounds.	Pounds per square inch.
Lithonia	2.00 x 2.00 x 2.02	76,000	....
Do	2.00 x 2.01 x 2.00	83,400	....
Lithonia (No. 3)	2.06 x 2.06 x 2.09	52,650	....
Lithonia	2.01 x 2.01 x 2.01	(a)	....
Do	2.00 x 1.98 x 1.98	(a)	....
Stone Mountain	2.05 x 2.00 x 2.01	(a)	....
Do	1.99 x 1.99 x 2.00	50,325	....
Do	1.99 x 1.99 x 2.00	48,760	....
Do	2.02 x 2.02 x 2.03	65,610	....

a Did not crush at 85,000 pounds pressure.

AT PURDUE UNIVERSITY, LAFAYETTE, IND.

Locality.	Dimensions (inches).	Pounds.	Pounds per square inch.
Lithonia	2.02 x 2.04 x 2.07	80,000	....
Do	2.02 x 2.01 x 2.06	61,000	15,024
Do	2.01 x 2.01 x 2.01	80,000	19,801
Do	2.01 x 2.00 x 2.00	80,700	....
Do	2.02 x 2.08 x 2.02	75,700	18,017
Do	2.02 x 2.05 x 2.02	64,000	15,455
Do	2.06 x 2.02 x 2.02	78,700	18,913
Do	2.04 x 2.04 x 2.06	71,700	17,229
Do	2.04 x 2.03 x 2.03	79,700	19,246
Do	2.04 x 2.04 x 2.05	79,700	19,151
Do	2.02 x 2.02 x 2.01	74,700	18,307
Do	2.01 x 2.02 x 2.04	70,700	17,413
Stone Mountain	2.00 x 2.01 x 2.02	50,000	12,438
Do	1.99 x 2.01 x 1.99	57,700	14,425
Do	2.04 x 2.04 x 2.05	53,700	12,904
Do	2.04 x 2.07 x 2.05	55,700	13,190
Do	2.01 x 2.03 x 2.02	54,700	13,406
Do	2.02 x 2.05 x 2.01	52,700	12,726

[a] Granite pavements, compiled by Venable Brothers, Atlanta, Ga., 1893.

STRUCTURAL FEATURES OF THE GRANITES.

JOINTS.

The principal granite masses in Georgia are cut by joints, but as a rule these are by no means so conspicuously developed as in many granite areas elsewhere in the United States. The large residual masses of the granite gneiss of Lithonia and the granite of Stone Mountain are cut by joints that are in the main widely spaced and not very conspicuous. In most places there are two sets of joints which intersect each other approximately at right angles, the best-developed ones having nearly due east-west and north-south courses. In many of the quarries the major set of joints approximates a true northeast-southwest direction.

In the Oglesby-Lexington area of dark blue-gray granite many of the outcrops are in the form of large and small rounded bowlders strewn loosely over the surface or partly buried in the residual clay. These bowlders have been derived from weathering along the joint planes which intersect the granite. Decay progressed more rapidly on the edges and corners than along the flat sides of the blocks, thus giving them their present form. In these bowlder areas the surface rock is as a rule partly weathered for some distance down, and care should be used in selecting rock for dimension work. Beneath the weathered material the quarries exhibit solid rock of excellent quality and furnish highly satisfactory dimension stone. Jointing in the Oglesby-Lexington area is sufficiently developed to aid materially in quarrying the stone.

SLICKENSIDES.

Subsequent movement in many of the quarries is indicated in the slickensided surfaces of the joints. Slickensides are conspicuously developed in the Stone Mountain, Lithonia, and Hancock-Putnam counties granite areas, where the surfaces of the joints are coated with smooth yellowish damourite, in many places grooved and striated from the movement.

DIKES AND VEINS.

Two sets of intersecting material, differing in texture and origin and to some degree in mineral composition, are common to the granitic rocks. On the basis of texture and composition these are divisible into true dikes and veins. They are not so conspicuous in the Georgia granites as in areas of similar rocks over other parts of the continent, and only very rarely do they interfere with the quarrying of dimension stone.

GRANITE DIKES.

Nearly vertical granite dikes, varying in width from a few inches to 40 feet, cut the rocks in places. They are dark blue-gray in color and of fine and even grain, and are composed of quartz, orthoclase, and plagioclase feldspars, and biotite as the principal minerals. Except for their finer-grained texture they can not be distinguished in hand specimens from granites of the Oglesby and other areas of blue-gray granite in the State. They are common to some of the porphyritic granites and gneisses, but have not been observed penetrating any of the even-granular granites. They cut the porphyritic granite of Hancock and Warren counties and the contorted granite gneiss of Meriwether County.

A chemical analysis of the specimens collected from a 40-foot dike cutting the porphyritic granite gneiss in Warren County gave the following results:

Analysis of granite dike in Warren County, Ga.

[T. L. Watson, analyst.]

SiO_2	68.76
Al_2O_3	16.80
Fe_2O_3	.99
CaO	2.72
MgO	1.00
Na_2O	4.82
K_2O	3.70
Ignition	.29
	99.08

This analysis should be compared with the analyses of the granites from the Elberton-Oglesby-Lexington and Fairburn-Newnan-Greenville areas (pp. 220, 225, 229).

APLITE DIKES.

Aplites have been observed in association with the granite masses only at Stone Mountain, on the northwest side of which several less than 6 inches in width are exposed in the quarries. The aplite is banded with pegmatite. Apart from its being more compact and of much finer grain, the aplite is readily distinguished in the hand specimen from the inclosing granite by its lighter color and by its small content of mica. Biotite is entirely absent and muscovite is only sparingly distributed through the rock. Here and there small crystals of red garnet are present.

The aplite is composed chiefly of the potash and soda feldspars and quartz. Stout laths of striated acidic plagioclase are numerous. The small percentage of lime (less than 1 per cent) and the large percentage of soda shown in the analysis below indicate the preponderance of the soda molecule (albite).

Analysis of aplite from Stone Mountain, Georgia.

[T. L. Watson, analyst.]

SiO_2	74.30
TiO_2	None.
Al_2O_3	14.73
Fe_2O_3	.78
MnO	Trace.
CaO	.90
BaO	None.
SrO	None.
MgO	Strong trace.
Na_2O	4.61
K_2O	4.52
H_2O	.21
P_2O_5	Trace.
	100.05

The mineral composition of the aplite computed from the above analysis is as follows:

Potash feldspar	26.69
Soda molecules	38.77
Lime molecules	4.45
Quartz	28.30

From the above calculations the ratio of soda molecules to lime molecules is 9 to 1, which corresponds to a lime-bearing albite of the composition Ab_9An_1.

PEGMATITE DIKES AND VEINS.

The pegmatite dikes of this region differ from the true granite dikes described above principally in texture. Some of them are true pegmatite intrusions of aqueo-igneous origin; others are as certainly true veins of segregation. They are common to the porphyritic and nonporphyritic granites and granite gneisses, and are characterized by the usual coarse-grained texture, being composed almost exclusively of large cleavable pink and white feldspar and quartz with some biotite and here and there a little muscovite. Some of the dikes are very extensive and are apparently deep seated; others are minute and are entirely inclosed by the granite. They are of irregular outline and cut the granite without regard to direction. Thin sections show the feldspar to be microcline, orthoclase, and plagioclase, with local microperthite. Nearly all degrees of variation in the proportion of feldspar to quartz are indicated.

ORIGIN OF PHENOCRYSTS IN THE PORPHYRITIC GRANITES.

The porphyritic feldspars in the Georgia granites are believed to have crystallized contemporaneously with that of the groundmass minerals after the magma had come to rest. The evidence favoring this belief consists in (1) the absence of definite arrangement among the phenocrysts; (2) the absence of phenocrysts from the border zones of the granite areas—that is, gradation from an interior porphyritic facies peripherally into an even-granular granite of coarse texture and the same mineral and chemical composition; (3) the absence of evidence of magmatic resorption or corrosion of the phenocrysts; and (4) the presence of abundant inclusions of the groundmass constituents in the phenocrysts. These facts are regarded by the writer to indicate that the phenocrysts of these granites were developed in place and are not, according to the old belief, of intratelluric origin.

RELATIONS OF THE GRANITES AND THE GRANITE GNEISSES.

The granites and granite gneisses of the Georgia Piedmont are genetically very closely related. Both are light to dark gray in color and even granular to porphyritic in texture, and both have suffered more or less the effects of pressure. The granite gneisses differ from the granites only in the banded structure induced in them through pressure metamorphism. As has been pointed out elsewhere, the granite gneisses represent unquestionable foliated phases of massive granites similar to those of the present areas but of an earlier period of intrusion.

VARIETIES OF GRANITE.

Mineralogically the granites of Georgia are divisible into three leading types—(1) biotite granite or granitite, under which most of the granites of the State are grouped; (2) muscovite-biotite granite; and (3) biotite-bearing muscovite granite, of which the granite of Stone Mountain is the best representative. Texturally and structurally the granites are grouped as even-granular massive granites, porphyritic granites, and granite gneisses.[a] The relationships of these three phases of the granitic rocks are established below.

EVEN-GRANULAR MASSIVE GRANITES.

GENERAL STATEMENT.

Granites of superior quality and variety, well suited for general building and monumental work, have long been known in Georgia. For many years the famous light-gray muscovite granite from Stone Mountain was the only type of Georgia granite generally known beyond the limits of the State. Within the past few years, however, several areas yielding a high-grade monumental granite have come somewhat prominently into favor. Developments have recently been made in other areas of the Georgia Piedmont region, and the local granite industry has steadily grown until Georgia now ranks as the first granite producer among the Southern States.

With two exceptions all the granites are biotite granites. Muscovite is usually present in variable amount and is very prominent as an accessory in several localities. Hornblende is entirely lacking. In color the even-grained granites vary from light gray through intermediate gray to a dark blue gray, and in texture from fine to medium grained. Both color and texture are fairly uniform for each type.

There are four principal areas of even-granular granites in Georgia that are commercially important at present, or will become so in the near future. These are the Oglesby-Lexington blue-gray granite area, comprising the counties of Elbert, Madison, and Oglethorpe; the Elberton-Echols Mill light-gray granite area, in Elbert and Oglethorpe counties; the Fairburn-Newnan-Greenville medium blue-gray granite area, comprising the counties of Campbell, Coweta, and Meriwether; and the Stone Mountain light-gray granite area in Dekalb County. Besides these there are numerous smaller areas widely distributed over the Piedmont region, the granite of which belongs to one or the other of the types of the four areas named above.

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[a] The term granite gneiss is here used to denote those gneisses that have been derived from original granites by metamorphism and that are, therefore, of igneous origin.

BLUE-GRAY GRANITE OF THE OGLESBY-LEXINGTON AREA.

GENERAL DESCRIPTION.

The Oglesby-Lexington belt of dark blue-gray granite has a northeast-southwest direction through parts of Oglethorpe, Madison, and Elbert counties for about 30 miles, with an average width of 4 to 6 miles. The accompanying map (fig. 18) shows the Oglesby-Lexington area of blue-gray granite and the Elberton–Echols Mill area of light-gray granite as a single area. A variable thickness of residual decayed granite mantles the fresh rock, but outcrops of the granite are rather common, as flat-surfaced areas along the stream courses and as large bowlder outcrops on the interstream areas. Both forms of outcrops usually afford good quarry sites, and numerous quarries have been opened, grouped chiefly about two principal centers—Lexington and Huching, in Oglethorpe County, and Oglesby, in Elbert County. A list of the principal quarries opened in this belt is given below.

The rock is a biotite granite of dark blue-gray color and fine, even grain. It is fairly uniform in texture and color throughout the area; local variation in color is noted here and there, but not to such an extent as to injure the stone. The granite works well under the hammer and takes an excellent polish, with a striking contrast between the cut and polished surfaces. Its uniformity in color and texture, fineness of grain, freedom from imperfections and blemishes, and great strength and durability give it first rank as a monumental stone. It is used almost entirely for monumental stock, and for this purpose is commercially the most important in Georgia. The area is traversed by several lines of railroad, which afford abundant transportation facilities.

The large number of openings made over the area from which the granite has been quarried show the vertical joints to be widely spaced, thus affording abundant opportunity for the quarrying of dimension stone. Only in one opening—the Hill quarry, near Oglesby—are the joints so closely spaced as to prevent the quarrying of dimension stone, and here in only a single zone of about 10 feet in width. Small pegmatite veins from a fraction of an inch to several inches wide intersect the granite in nearly every opening, but only in one quarry are they so abundant as to interfere seriously with quarrying. These veins consist of coarse crystallizations of quartz and feldspar with scant muscovite and biotite.

MICROSCOPIC CHARACTERS.

This granite consists of anhedra of an average size of 0.5 to 1.5 millimeters. The principal minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, biotite, some muscovite, a little included apatite and zircon, and occasional grains of magnetite and pyrite. The secondary constituents are chlorite, epidote, muscovite, and kaolin. Much of the quartz occurs as droplike inclusions in the large feldspar individuals; and locally it is intergrown with a part of the feldspar in the form of ovals or rounded disks of granophyric structure. Orthoclase is the dominant feldspar and exhibits in places microperthitic intergrowths with a triclinic feldspar. Microcline varies in quantity, but may equal the orthoclase. Twinning on the

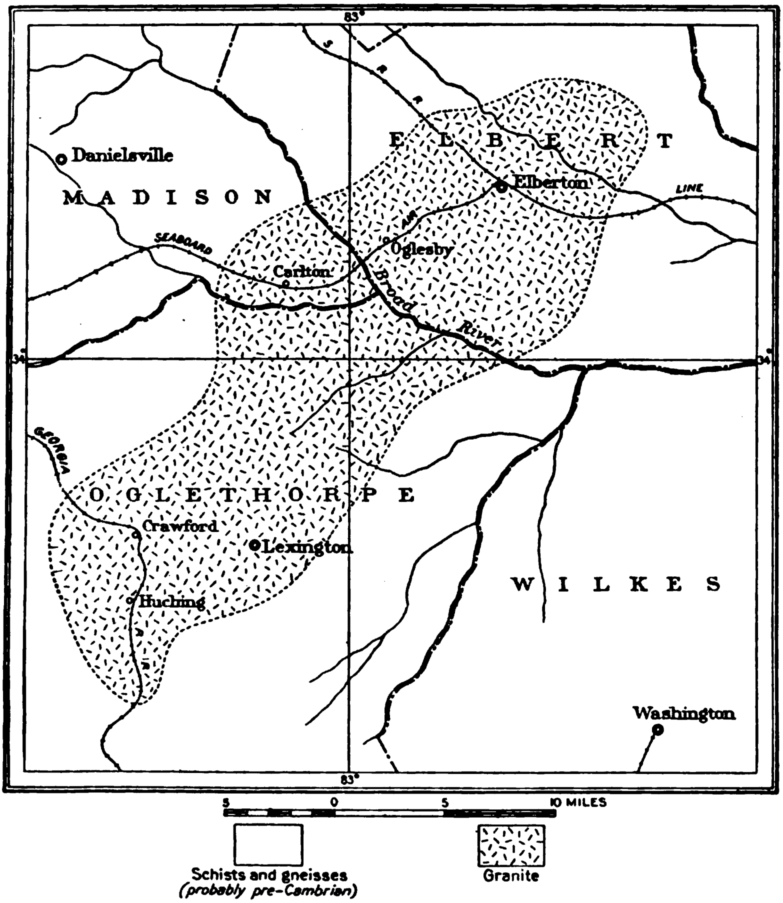

FIGURE 18.—Map of Oglesby-Lexington and Elberton-Echols Mill granite areas, Georgia.

Carlsbad law is common to the potash feldspars. Plagioclase is present in large amount and in most sections equals or exceeds orthoclase. As a rule, low extinction angles in basal sections characterize the plagioclase—a fact which, with the percentage of lime given in the analyses, indicates oligoclase. Biotite is regularly distributed through the rock in single shreds of deep-brown color and strong pleochroism. It is intimately associated with muscovite, which is usually present in smaller amount but here and there may equal the biotite. The biotite is partly altered to chlorite.

CHEMICAL COMPOSITION.

The following chemical analyses of the dark blue-gray granite from the Oglesby-Lexington area were made by the writer in the chemical laboratory of the Georgia Survey:

Analyses of dark blue-gray granite from the Oglesby-Lexington area, Georgia.

	1.	2.	3.	4.	5.	6.	7.
Silica (SiO_2)	70.30	70.18	70.03	69.53	69.36	69.64	70.38
Alumina (Al_2O_3)	16.17	17.30	15.62	16.46	17.23	17.21	16.47
Iron oxide (Fe_2O_3)	1.19	1.20	1.31	1.15	1.43	1.32	1.17
Magnesia (MgO)	.31	.64	.52	.85	.59	.66	.31
Lime (CaO)	2.61	2.03	2.45	2.10	2.14	2.14	1.72
Soda (Na_2O)	4.72	4.36	4.82	5.00	5.17	4.53	4.98
Potash (K_2O)	4.88	4.77	5.42	4.91	4.57	4.95	5.62
Ignition	.63	.35	.77	.91	.33	.35	.31
Specific gravity	2.666	....	2.666	....	2.665	....	....

1. Diamond Blue Granite Company's quarry, near Huching, Oglethorpe County.
2. Brown & Deadwyler quarry, Madison County.
3. Lexington Blue Granite Company's quarry, Lexington, Oglethorpe County.
4. Huching quarry, Oglethorpe County.
5. Childs quarry, near Oglesby, Elbert County.
6. Hill quarry, near Oglesby, Elbert County.
7. Etheridge quarry, 3 miles east of Oglesby, Elbert County.

According to the definition given by Brögger the above analyses show the rock of this belt to be quartz monzonite.

PHYSICAL TESTS.

The ratio of absorption of these granites was determined by the writer in the Georgia Survey laboratory on carefully selected specimens from a number of quarries in this belt, with the following results:

Absorption of granite from Oglesby-Lexington area, Georgia.

	Percentage of absorption.
Lexington blue-granite quarry, Oglethorpe County	0.092
Diamond blue-granite quarry, Oglethorpe County	.088
Coggins quarry, Elbert County	.090
Childs quarry, Elbert County	.092

The above figures indicate a compact, close-grained rock that will not be appreciably affected by frost action.

Tests made on specimens of the Diamond Blue Granite Company's granite at the Watertown Arsenal January 17, 1894, illustrate the compressive crushing strength of the dark blue-gray granite of the Oglesby-Lexington granite area.

Compressive strength of granite from Diamond Blue Granite Company's quarry, Oglethorpe County, Ga.

Test No.	How tested.	Size (inches).	Pressure (pounds per square inch).
7304	On bed......	3.07 x 3.06 x 3.04	26,340
7307	On grain....	3.16 x 2.99 x 3.10	23,860

DESCRIPTIONS OF QUARRIES.

INTRODUCTORY STATEMENT.

A list of the quarries, both large and small, opened in the belt of dark blue-gray granite follows. Some of the openings listed are small and the production from them has been very meager. Only two were operating during the summer of 1908, namely, the Deadwyler (Collins & Venable) and the Etheridge.

Quarries in the Oglesby-Lexington belt of dark blue-gray granite.

Oglethorpe County:	
Arnold	1½ miles west of Huching.
Diamond Blue Granite Company	2 miles southwest of Huching.
Heath	2 miles west of Huching.
Lexington Blue Granite Company	One-half mile west of Lexington.
Willingham	1½ miles northwest of Crawford.
Madison County:	
Brown & Deadwyler	2½ miles south of Carlton.
David	2 miles west of Carlton.
Elbert County:	
Long Granite Company's quarries—	
Coggins	1½ miles southwest of Oglesby.
Deadwyler (Collins & Venable)	1½ miles southwest of Oglesby.
Hill	1 mile southwest of Oglesby.
Etheridge	3 miles east of Oglesby.
Bisson	1½ miles southwest of Oglesby.
Childs	1 mile southwest of Oglesby.
Seaboard	One-half mile northeast of Oglesby.

ELBERT COUNTY.

The *Coggins quarry*, opened in 1882 in a bowldery outcrop of the granite, is about 1½ miles southwest of Oglesby. It has been operated at intervals since its opening. The rock is a biotite granite of dark blue-gray color and fine, even grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), together with accessory apatite and zircon and secondary chlorite.

Chemical analyses of the fresh and decayed granite gave the following results:

Analyses of granite from Coggins quarry, near Oglesby, Ga.

[T. L. Watson, analyst.]

	Fresh.	Decayed.
Silica (SiO_2)	69.74	60.94
Alumina (Al_2O_3)	16.72	23.29
Iron oxide (Fe_2O_3)	1.45	2.44
Lime (CaO)	1.93	.04
Magnesia (MgO)	.36	.43
Soda (Na_2O)	4.84	2.18
Potash (K_2O)	4.33	3.57
Ignition	.47	8.03

The specific gravity is 2.84 and the percentage of absorption is 0.090.

This granite does not contain any blemishes; it takes a high polish, works well under the hammer, and shows strong contrast between the hammered and polished surfaces.

The *Deadwyler* (*Collins & Venable*) *quarry* is near the Coggins quarry, about 1,900 feet north of the Seaboard Air Line Railway. It is opened in a bowldery outcrop, and in some places decayed material is visible along the joint surfaces to the entire depth of 40 feet. (See Pl. V, *B*.) The stone is identical in mineral composition, color, and texture with the granite of the Coggins quarry. About 568 cubic yards of it was quarried in 1891 for bridge piers along the Seaboard Air Line. The quarry was operating during 1908 to supply monumental stock exclusively.

The *Hill quarry* is a mile southwest of Oglesby, directly south of the Seaboard Air Line Railway. It has been worked to a depth of 40 feet and during its period of activity it was probably the most extensive quarry in the Oglesby portion of the area. It has been idle for some years. The rock is a biotite granite of the same color, texture, and mineralogy as the granite of the Coggins quarry. Magnetite is sparingly present in some of the thin sections. Vertical joints strike east-west and north-south, and except in a 10-foot zone at the south end of the quarry, the joints are sufficiently far apart to permit the quarrying of dimension stone. Weathering along some of the joints extends to the depth of working—40 feet. A chemical analysis of the granite, made by the writer, is given on page 220 (No. 6).

The *Etheridge quarry* is about 3 miles east of Oglesby, directly southeast of the Seaboard Air Line Railway. It was opened in 1893, in a sloping surface exposure of the granite, and in places is worked to a depth of 20 feet or more. It was one of the two quarries in the Oglesby area operating during the summer of 1908. The rock is biotite granite of medium-gray color and fine, even grain. It is somewhat lighter in color than the granite quarried in the immediate vicinity of Oglesby. On account of this difference the company designates the two granites "Oglesby dark-blue" and "Oglesby light-blue" granite. It differs in mineral composition from the granite nearer Oglesby only in possessing slightly more muscovite. A chemical analysis of the granite is given on page 220 (No. 7).

The *Childs quarry*, 800 yards east of the Hill quarry, is in an excellent body of the fine even-grained dark blue-gray granite. Quarrying was discontinued many years ago because of the large waste occasioned by the numerous dikes of pegmatite. These vary in thickness from a fraction of an inch to many inches and cut the granite indiscriminately. A chemical analysis of the granite is given on page 220.

The *Seaboard quarry* is immediately south of the Seaboard Air Line Railway about half a mile northeast of Oglesby. The rock is a biotite granite of dark blue-gray color and fine grain, similar in all respects to the granite quarried by the Long Granite Company near by. The quarry is operated at intervals by the Seaboard Air Line Railway to supply crushed stone for ballast. It was idle at the time of the writer's visit in July, 1908, and was reported to have suspended work in September, 1907.

MADISON COUNTY.

The *Brown & Deadwyler quarry* is near the confluence of the north and south forks of Broad River, about 2½ miles south of Carlton. The opening, made about fifteen years ago, is a small one in large bowlder outcrops. In mineral content, color, and texture the granite is identical with that quarried near Oglesby. A chemical analysis of it is given on page 220 (No. 2).

OGLETHORPE COUNTY.

The *Diamond Blue Granite Company's quarry* comprises four openings some distance apart, about 2 miles southwest of Huching. The openings are on both sides of a small stream, and the principal one is in a 20° to 30° slope of exposed granite. The product, which was used almost exclusively for monuments, was shipped to various points outside of the State.

The rock is a biotite-muscovite granite of dark blue-gray color and fine, even grain. The feldspars have a decided bluish-gray tone and in descending order of abundance, comprise microperthitic orthoclase, microcline, and a soda-lime feldspar near oligoclase. Muscovite nearly equals the biotite in amount. A few pegmatite dikes of slight thickness cut the granite. Two chemical analyses made by the writer from specimens collected from the four openings averaged as follows:

Average analysis of granite from Diamond Blue Granite Company's quarry, near Huching, Ga.

Silica (SiO_2)	69.915
Alumina (Al_2O_3)	16.315
Iron oxide (Fe_2O_3)	1.170
Lime (CaO)	2.355
Magnesia (MgO)	.580
Soda (Na_2O)	4.860
Potash (K_2O)	4.895
Ignition	.770

Results of tests of the compressive crushing strength and the percentage of absorption of the granite are given on pages 220, 221.

The *Lexington Blue Granite Company's quarry* is half a mile west of the court-house at Lexington. The granite outcrops as flat masses and bowlders over a considerable area over the south slope of Town Creek. Half a dozen openings have been made. The rock is a biotite granite of dark blue-gray color and fine, even grain. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with considerable white mica (muscovite) and the usual accessory and secondary minerals. Micrographic intergrowths of quartz and feldspar are abundant. Pegmatite dikes varying from a fraction to several inches in thickness cut the granite in many places. A chemical analysis of the granite is given on page 220 (No. 3). The ratio of absorption is 0.092.

LIGHT-GRAY GRANITE OF THE ELBERTON–ECHOLS MILL AREA.

GENERAL DESCRIPTION.

The light-gray granite of the Elberton–Echols Mill area is represented by a belt of approximately the same dimensions and general direction as the dark blue-gray granite of the Oglesby-Lexington area, which lies immediately adjacent on the southeast. The two areas are well differentiated as to color, and in a less degree as to texture, in their extreme portions, but they undoubtedly form parts of the same general area, as the gradation is well shown near Elberton and Carlton. The two areas are mapped together in figure 18.

The rock is a biotite granite of light-gray color and medium even-grained texture. Slight local variation in color and texture is noted. The granite is well suited to all grades of constructional work. Dimension stone is readily obtained and the rock works well under the hammer. Pegmatite veins and dark segregations, chiefly of biotite, are observed here and there in some of the openings, but these can readily be avoided without waste in working. The principal openings in this belt of granite are grouped about Elberton, in Elbert County. The rock has been used chiefly for building purposes to supply the local market.

The light-gray granite of the Elberton–Echols Mill area does not differ essentially in mineral composition from the dark blue-gray granite of the Oglesby-Lexington area, although the two contrast strongly in hand specimens. The difference is essentially one of color, the biotite being distributed at greater intervals and in somewhat shorter aggregated shreds in the light-gray granite. As a rule, the light-gray rock is a little more coarsely crystalline in texture than the dark blue-gray rock. The same minerals are present in nearly the same proportions and they show the same characteristics in the two types. Orthoclase, microcline, acidic plagioclase (oligoclase), quartz, biotite, a little muscovite, apatite, and zircon are the primary minerals.

CHEMICAL COMPOSITION.

The following analyses, made in the Georgia Survey laboratory by the writer, serve to illustrate the composition of the light-gray granite of the Elberton–Echols Mill area. Analyses 1, 2, and 3 represent the typical light-gray granite; analysis 4, the rock intermediate between the Oglesby dark blue-gray and the Elberton light-gray types.

Analyses of granite from Elberton–Echols Mill area.

	1.	2.	3.	4.
Silica (SiO_2)	68.81	69.45	69.25	71.00
Alumina (Al_2O_3)[a]	17.67	15.93	16.04	16.33
Iron oxide (Fe_2O_3)[b]	1.13	1.31	1.72	1.12
Magnesia (MgO)	.50	.55	.31	.35
Lime (CaO)	2.17	1.91	1.89	1.83
Soda (Na_2O)	4.97	4.33	4.52	4.80
Potash (K_2O)	3.90	5.16	4.49	4.65
Ignition	.30	.50	.43	.87
	99.45	99.14	99.10	100.95
Specific gravity	2.657	2.652	2.670	....

[a] Contains traces of P_2O_5, TiO_2, and ZrO_2 when present.

[b] All iron estimated as Fe_2O_3.

1. Echols Mill, Oglethorpe County.
2. Swift & Wilcox, Elbert County.
3. Tate & Oliver, Elbert County.
4. Fortson, Elbert County.

ABSORPTION TESTS.

The percentage of absorption of the light-gray granite of the Elberton-Echols Mill area is from 0.090 to 0.092 at the Swift & Wilcox quarry, near Elberton, and 0.093 at the Tate & Oliver quarry at Elberton.

DESCRIPTIONS OF QUARRIES.

INTRODUCTORY STATEMENT.

The principal openings made in the light-gray granite are in the vicinity of Elberton, Elbert County. Most of these are very small. About half of them are in granite intermediate in color and texture between the dark blue-gray of Oglesby and the light-gray of Elberton, and mark the passage of one type into the other. In the Echols Mill portion of the area, in Oglethorpe County, extensive exposures of the light-gray granite are numerous and good quarry sites are readily obtained, but the distance from transportation lines is a barrier to development. No openings of sufficient size to be called quarries have been made in the Echols Mill area. The quarries and openings worked in the light-gray granite are listed below:

Quarries and openings in the light-gray granite of the Elberton–Echols Mill area.

Elbert County:	
Adams [a]	4½ miles northeast of Elberton.
Carlton [a]	1¼ miles northeast of Elberton.
Fambrough	¾ mile south of Elberton.
Fortson [a]	½ mile northeast of Goss.
Heard	1 mile southwest of Elberton.
Hester [a]	1½ miles northwest of Elberton.
Swift & Wilcox	1 mile south of Elberton.
Tate & Oliver	½ mile northeast of Elberton.
Oglethorpe County:	
Andrew	2 miles southeast of Carlton.
Arnold	10 miles northeast of Lexington.
Echols Mill	11 miles northeast of Lexington.

ELBERT COUNTY.

The *Adams quarry*, comprising two openings 150 feet apart, is 4½ miles northeast of Elberton. The granite outcrops as large bowlders over approximately 5 acres of surface. Several bowlders were worked up in 1885 and 1886 for local purposes. In 1890 a large quantity of stone was quarried for bridge piers in the construction of the Seaboard Air Line Railway bridge over Savannah River. The rock is a biotite granite of medium blue-gray color and medium-fine grain. It is intermediate in color and texture between the Oglesby dark blue-gray and the Elberton–Echols Mill light-gray types. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with a little white mica (muscovite), and the accessories apatite, zircon, and magnetite. Secondary chlorite and epidote occur. A chemical determination of silica gave 69.41 per cent. The sap (partly weathered granite) is very thin. The granite takes a good polish, works well under the hammer, and is desirable for either monumental or general architectural purposes.

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[a] Granite intermediate in color and texture between the dark blue-gray of Oglesby and the light-gray of Elberton, and marking the transition of one type into the other.

The *Swift & Wilcox quarry*, opened in 1888 and worked at intervals since, comprises two openings close together, a mile south of Elberton. A stripping of 3 to 6 feet is necessary in the larger opening. Flat-surfaced and bowlder exposures of the granite are abundant in the vicinity of the quarry. The rock is a biotite granite of light-gray color and even, medium grain. It is entirely massive and uniform in color and texture. It has been regarded by the writer as the typical light-gray granite of the Elberton–Echols Mill area. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with a little white mica (muscovite); accessory apatite and zircon are sparingly present. The biotite is partly altered to chlorite. The potash feldspar exceeds plagioclase. Micropegmatitic intergrowths of quartz and feldspar are common. Chemical analyses of the fresh and partly decayed granite from this quarry gave the following results:

Analyses of granite from Swift & Wilcox quarry, near Elberton, Ga.

[T. L. Watson, analyst.]

	Fresh.	Partly decayed.
Silica (SiO_2)	64.45	69.00
Alumina (Al_2O_3)	15.93	17.31
Iron oxide (Fe_2O_3)	1.31	1.31
Lime (CaO)	1.91	1.18
Magnesia (MgO)	.55	.42
Soda (Na_2O)	4.33	4.00
Potash (K_2O)	5.16	4.74
Ignition	.50	1.79

Small dikes of pegmatite, and a few small dark areas (knots) occur here and there. Results of physical tests made on specimens of the granite are given on page 225.

The *Tate & Oliver quarry* is located in Pinetown, a district of Elberton, about half a mile northeast of the court-house. The larger part of a 2-acre flat-surfaced exposure has been worked to a depth of less than 15 feet. The rock is a biotite granite of the same color, texture, and mineral composition as the light-gray type from the Swift & Wilcox quarry, described above. A chemical analysis of this granite made by the writer is given on page 225. The percentage of absorption is 0.093.

OGLETHORPE COUNTY.

The light-gray granite is abundantly exposed in the north-central portion of Oglethorpe County at and near Echols Mill, 12 miles northeast of Lexington. Extensive outcrops occur at Echols Mill and are in every respect identical in color, texture, and mineral composition with the granite of the Swift & Wilcox quarry, near Elberton, in Elbert County. The light-gray type has not been quarried in Oglethorpe County.

Thin sections of the Echols Mill light-gray granite show the minerals to be potash feldspars (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), together with accessory apatite, zircon, and magnetite The biotite is partly altered to chlorite. A chemical analysis of this granite is given on page 225 (No. 1).

MEDIUM-GRAY GRANITE OF THE FAIRBURN-NEWNAN-GREENVILLE AREA.

GENERAL DESCRIPTION.

The medium-gray type of the Fairburn-Newnan-Greenville area traverses Campbell, Coweta, and Meriwether counties in a nearly north-south course, quarries being opened near Fairburn, Newnan, and Greenville, the respective county seats. A similar granite has been quarried in the vicinity of Griffin, Spaulding County, for strictly local use. Coarsely crystalline porphyritic granites and gneisses of essentially the same mineral and chemical composition as the even-granular type are found in intimate association with it over parts of Campbell, Coweta, and Meriwether counties.

The even-granular massive biotite granite of this area comprises two varieties. One, a medium-gray, is an average fine-textured rock; the other, a dark blue-gray granite occurring in the southwest part of Meriwether County, is more coarsely crystalline and darker in color and contains a larger proportion of biotite than the medium-gray type. Variation in color and texture of the even-grained granites in general is very slight over the area. In the northern part of the area, near Fairburn, the granite is somewhat lighter in color, and in the middle and southern parts, near Newnan and Greenville, it is correspondingly darker. This type is closely similar in mineral and chemical composition to the dark blue-gray of the Oglesby-Lexington area and the light gray of the Elberton-Echols Mill area described above, and is intermediate between the two in color and texture.

MICROSCOPIC CHARACTERS.

The primary constituents are orthoclase, microcline, plagioclase near oligoclase, quartz, biotite, a little muscovite, apatite, and zircon. Secondary epidote and chlorite from the alteration of feldspars and biotite are usually present. A few garnets have been noted in several places in the northern part of the area. The orthoclase is intergrown in part with a second feldspar, acidic plagioclase, as microperthite. Microcline is nearly absent in some places and is very abundant in others. Acidic plagioclase is a constant constituent and in some thin sections it equals or exceeds in amount the potash feldspars. Biotite is variable in amount and is everywhere the principal accessory. Muscovite, usually present in small quantity, is intimately associated with the biotite. Epidote occurs in irregular grains and is rather common as large idiomorphic crystals in thin sections of the granite from the Cole quarry, near Newnan.

CHEMICAL COMPOSITION.

The chemical composition of the granite from the Fairburn-Newnan-Greenville area is shown in the analyses below, which were made by the writer in the laboratory of the Georgia Survey:

Analysis of granite from the Fairburn-Newnan-Greenville area, Georgia.

	Carmichael.	Greenville Granite Co.	Cole.	Overby.	Hill.
Silica (SiO_2)	69.55	69.88	69.08	69.07	68.38
Alumina (Al_2O_3)	16.72	16.42	17.67	16.56	17.79
Iron oxide (Fe_2O_3)	.99	1.96	1.41	1.37	1.21
Magnesia (MgO)	.27	.36	.64	.76	.72
Lime (CaO)	1.69	1.78	3.27	1.83	1.76
Soda (Na_2O)	5.88	4.46	4.56	4.65	4.36
Potash (K_2O)	3.94	5.63	3.29	5.02	3.57
Ignition	.27	.36	.56	.92	.78
	99.31	100.85	100.48	100.18	99.66
Specific gravity	2.658	2.662	2.700	....	2.689

Considered singly, three of the analyses (Carmichael, Cole, and Hill quarries) show an excess of soda over potash, and the rock from these quarries is more properly designated quartz monzonite. In the two remaining analyses (Greenville Granite Company and Overby quarries) the soda content is quite large, but is inferior in amount to the potash. An average of the alkalies for the five analyses shows an excess of soda over potash of about 0.5 per cent, a fact which would group the even-granular acidic plutonic rocks of this area with the quartz monzonites. The high soda content in each of the analyses is a noteworthy feature.

ABSORPTION TEST.

The percentage of absorption of the granite of this area corresponds closely with that of the dark blue-gray and light-gray belt of Oglethorpe and Elbert counties described above. The percentage of absorption of the granite from the Greenville Granite Company's quarry in Meriwether County was found to be 0.086.

DESCRIPTIONS OF QUARRIES.

INTRODUCTORY STATEMENT.

Practically no systematic quarrying has been carried on in any part of the area. Five quarries have been worked as follows:

Quarries in the Fairburn-Newnan-Greenville area, Georgia.

Meriwether County:	
Greenville Granite Company	1 mile northeast of Greenville.
Coweta County:	
Hill	3¼ miles east of Newnan.
Cole	One-half mile east of Newnan.
Overby	10 miles east of Newnan.
Campbell County:	
Carmichael	2¼ miles N. 25° E. of Fairburn.

Practically none of the stone from this area has been marketed outside of the State. The granite is of homogenous color and texture, and is admirably adapted for general building and constructional work, and in places for monumental stock. It has been used locally for nearly all grades of work, such as buildings, monuments, cemetery coping and retaining walls, and railroad construction.

The openings are in bowlder and flat-surfaced exposures, the common form of outcrops. Most of the outcrops are of large dimensions and practically free from soil covering. The quarries are well located with reference to transportation by rail and admit of easy working. The most extensive areas of the granite and the largest quarries are mainly in Coweta and Meriwether counties. Jointing is not very conspicuously developed and the planes are always widely spaced, permitting the quarrying of dimension stone. Dikes of pegmatite and fine granite are rare, and the rock is generally free from deleterious minerals.

CAMPBELL COUNTY.

The *Carmichael quarry*, opened in an area of bowlder outcrops covering 10 to 15 acres, lies on the east side of the Altanta and West Point Railroad, about 2¼ miles N. 25° E. of Fairburn. It was opened in 1898 to supply stone for coping and monuments for the cemetery in Jacksonville, Fla. Thirty-five cars of the stone were shipped by June, 1899. The rock is a biotite granite of medium-gray color and even, fine grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), with secondary chlorite, epidote, and a light-colored mica. A chemical analysis of this granite is given on page 229. A few pegmatite dikes of slight thickness cut the rock. The vertical joints strike northwest-southeast and their surfaces are slickensided, indicating some movement in the mass. The rock is susceptible of a high polish.

COWETA COUNTY.

The *Cole quarry* is opened in a flat-surfaced exposure of granite less than 1 acre in extent half a mile east of Newnan. It was opened about eighteen years ago and is worked to a depth of about 30 feet. The product has been used mostly for building purposes in the town of Newnan. The rock is a biotite granite of dark-gray color and medium-fine, even grain. Scattered folia of muscovite are visible to the naked eye. In the hand specimens the rocks resemble somewhat closely the dark-gray granite of Oglesby. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), with accessory apatite and zircon. The secondary minerals are chlorite, epidote, and a light-colored mica. Epidote occurs both in irregular grains and in platy form with partial crystal outline. Chemical analyses of the fresh and decayed granite gave the following results:

Analyses of granite from Cole quarry, Coweta County, Ga.

[T. L. Watson, analyst.]

Constituents.	Fresh.	Decayed.
Silica (SiO_2)	69.08	56.99
Alumina (Al_2O_3)	17.67	26.02
Iron oxide (Fe_2O_3)	1.41	1.91
Magnesia (MgO)	.64	.17
Lime (CaO)	3.27	.75
Soda (Na_2O)	4.56	1.91
Potash (K_2O)	3.29	2.40
Ignition	.56	9.76

The decayed rock extends to a depth of 15 feet below the surface. Within this zone the granite is sheeted, the sheets being thinnest near the surface and merging below into perfectly massive rock. The vertical joints strike east-west and north-south, the two sets having about equal development. There are numerous dikes of pegmatite, most of which strike north and south. Small areas of biotite chiefly (knots) occur.

The *Hill quarry*, opened in a ledge on the east side of White Oak Creek, is 3½ miles nearly east of Newnan. It was first opened about 1888 to supply stone for the Central of Georgia Railway. The opening is only a few feet above stream level. The rock is a biotite granite of medium dark-gray color and medium-fine, even grain. Scattered shreds of muscovite are visible to the unaided eye. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), with accessory apatite and zircon. Chlorite and epidote occur as secondary minerals. A chemical analysis of this granite is given on page 229.

The vertical joints strike S. 35° E. Numerous thin dikes of a fine-grained biotite granite, striking approximately northwest to southeast, cut the main mass. The stone takes a good polish.

The *Overby quarry* is opened in a 2-acre flat-surfaced exposure 10 miles east of Newnan. Its long distance from the railroad has hindered its development. The small quantity of stone quarried was used for monument bases, sills to windows and doors, and retaining walls in cemeteries. The rock is a biotite granite of medium-gray color and medium-fine, even grain. It resembles very closely that from the Carmichael quarry in Campbell County (p. 230). It is a shade coarser in texture and lighter in color than that from the Cole and Hill quarries, described above. In mineral composition it is identical with these granites. A chemical analysis, made by the writer, is given on page 229.

MERIWETHER COUNTY.

The *Greenville Granite Company's quarry*, 1 mile northeast of the court-house at Greenville, is opened in a bowlder outcrop of granite. Similar outcrops extend over a considerable area. The product was used chiefly for cemetery and building purposes in Columbus, Ga. The rock is a biotite granite of dark blue-gray color and medium-fine, even grain. Scattered shreds of muscovite and Carlsbad twins of orthoclase are visible in the hand specimens. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), with accessory apatite, zircon, and rutile. The biotite is partly altered to chlorite. The orthoclase is intergrown with a second feldspar. Rounded areas of quartz and feldspar are inclosed in the larger grains of the two minerals. Chemical analyses of the fresh and decayed granite from this quarry gave the following results:

Analyses of granite from Greenville Granite Company's quarry, near Greenville, Ga.

[T. L. Watson, analyst.]

Constituents.	Fresh.	Decayed.
Silica (SiO_2)	69.88	51.29
Alumina (Al_2O_3)	16.42	29.69
Iron oxide (Fe_2O_3)	1.96	6.33
Magnesia (MgO)	.36	.14
Lime (CaO)	1.78	.07
Soda (Na_2O)	4.46	1.12
Potash (K_2O)	5.63	1.50
Ignition	.36	10.36

The specific gravity is 2.662 and the percentage of absorption is 0.086. This granite resembles very closely that quarried in the Oglesby area in Elbert County, described on pages 221–223, except that the latter is a shade darker in color and slightly finer grained. Both are susceptible of a high polish.

LIGHT-GRAY GRANITE OF STONE MOUNTAIN.

GENERAL DESCRIPTION.

The light-gray granite of Stone Mountain (map, fig. 19) is strongly contrasted with all other types of granite in Georgia. It differs from them in mineral composition in its large preponderance of muscovite over biotite, which, though invariably present, occurs in very small quantity. The rock is therefore a biotite-bearing muscovite granite. It is uniformly light gray in color over the entire area, but in places shows slight variation in texture. It is intermediate between the other types of even-granular granites on the one hand and the coarsely crystalline matrix of the porphyritic granites on the other. The potash feldspars predominate, with orthoclase usually in excess of microcline. The orthoclase is locally intergrown with a second feldspar in microperthitic structure.

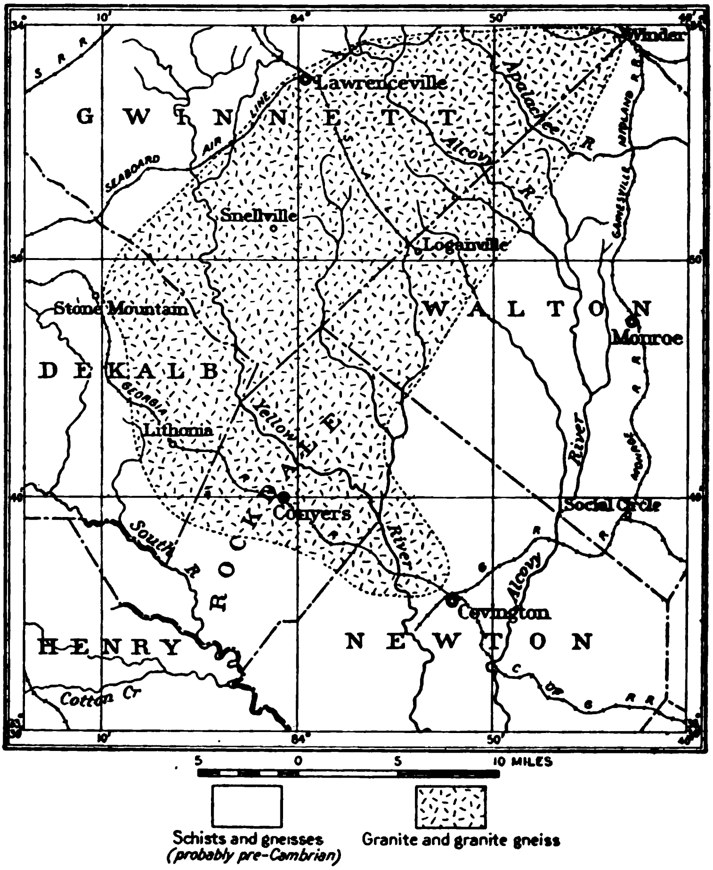

FIGURE 19.—Map of Stone Mountain and Lithonia-Conyers-Lawrenceville granite and gneiss area, Georgia.

The microcline is subject to considerable variation in amount, equaling orthoclase in some sections and sinking to a minimum in others. Plagioclase is present in large amount as stout laths twinned on the albite law; the lamellæ usually give low extinction angles in basal sections. Micropoikilitic structure is developed in the larger feldspar individuals. The small quantity of biotite is intimately associated with the muscovite. Accessory apatite and zircon and some secondary chlorite occur.

Several minerals not usually seen in the sections of the granite from Stone Mountain are common constituents of the rock. The most abundant of these is black tourmaline, which is present in nearly every large block of the stone quarried. The tourmaline occurs rarely as single crystals distributed through the granite, but mostly as radiating and roughly parallel groups that occupy white areas of quartz and feldspar from which the two micas, muscovite and biotite, have been excluded. These quartz-feldspar areas vary from a fraction of an inch to several inches in diameter and from oblong to circular outlines. The tourmaline individuals are of slender prismatic form, varying from a fraction of a millimeter to several millimeters in cross section without terminal faces; they are jet black in color and are as a rule considerably fractured. These tourmaline areas are not sufficiently numerous in the granite nor large enough to affect the color of the rock, and, though clearly visible, they do not in any measure detract from the good qualities of the stone for general building purposes. Small crystals of red garnet are not uncommon. The surfaces of some of the joints are thinly incrusted with a mixture of uranophane and hyalite.

At Constitution, about 6 miles southeast of Atlanta and about 12 miles southwest of Stone Mountain, is a second exposure of a biotite-bearing muscovite granite of light-gray color and fine grain. A small quantity of the rock has been quarried and used chiefly for monuments. It consists of the same minerals in the same proportions as at Stone Mountain. Intergrowths of quartz and feldspar are common. The prismatic inclusions of apatite are in places bent and broken, indicating pressure effects on the granite mass.

CHEMICAL COMPOSITION.

The composition of the granite of Stone Mountain is shown in analyses 1 and 2, below; analysis 3 is that of an aplite which intersects the granite.

Analyses of granite from Stone Mountain, Georgia.

Constituents.	1.	2.	3.
Silica (SiO_2)	72.56	71.66	74.30
Alumina (Al_2O_3)	14.81	16.05	14.73
Iron oxide (Fe_2O_3)	.94	.86	.78
Magnesia (MgO)	.20	.17	Trace.
Lime (CaO)	1.19	1.07	.90
Soda (Na_2O)	4.94	4.66	4.61
Potash (K_2O)	5.30	4.92	4.52
Ignition	.70	1.00	.21
Phosphoric oxide (P_2O_5)	Not det.	Not det.	Trace.
	100.64	100.39	100.05

1. Fresh granite, Stone Mountain, Georgia. R. L. Packard, analyst.
2. Granite spall exposed for three or four years, Stone Mountain, Georgia. R. L. Packard, analyst.
3. Aplite, Stone Mountain, Georgia. T. L. Watson, analyst.

PHYSICAL TESTS.

Four crushing-strength tests of 2-inch cubes of granite from Stone Mountain gave 85,000, 50,325, 48,760, and 65,610 pounds, equivalent to 21,250, 12,581, 12,190, and 16,402 pounds per square inch. A similar series of strength tests made in 1890 at Purdue University, Lafayette, Ind., gave 12,438, 14,425, 12,904, 13,190, 13,406, and 12,726 pounds per square inch. Another series of tests made at the Watertown Arsenal gave 25,630 and 28,130 pounds per square inch, on bed.

DESCRIPTION OF QUARRIES.

In addition to the Stone Mountain quarries, which are the most extensive in the State, about half a dozen small quarries have been worked nearby in the adjacent lowland belt of the same granite. All the quarries opened in the Stone Mountain type of granite are located in Dekalb County. The quarries in this area are listed below.

Dekalb County, Ga., quarries in the light-gray granite near Stone Mountain.

Constitution[a]	6 miles south of Atlanta.
Nash & McCurdy	3 miles east of Stone Mountain.
Shepard	2½ miles south of Stone Mountain.
Stone Mountain	1 mile east of Stone Mountain.
Thomas	6 miles southeast of Stone Mountain.
Thompson	2 miles northeast of Stone Mountain.
Veal	3 miles east of Stone Mountain.
Wiggins	1 mile north of Redan.

Stone Mountain, which is a huge doming ridge of granite (Pl. XXV, *A*), is situated about 16 miles east of Atlanta in Dekalb County. It is an elliptical boss, with its longer axis trending northeast and southwest and its steepest side facing northward. It rises 686 feet above the adjacent lowland plain of crystalline rocks, and measures 7 miles in circumference around its base. The present ridge is the unreduced remnant of a much larger granite mass. The evidence favoring this conclusion is the fact that a belt of the same granite reduced to the general level of the surrounding Tertiary Piedmont plain skirts the north, west, and south sides of the ridge with a width varying from a quarter of a mile to more than a mile.

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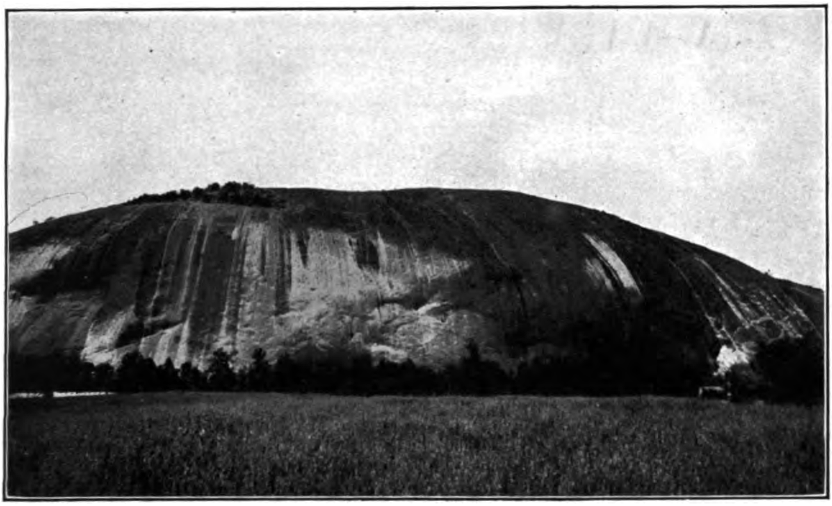
[a] The Constitution granite quarry is not in the Stone Mountain area, but is listed here because it is located in Dekalb County.

The granite of Stone Mountain and the granite gneiss of the adjacent Lithonia area in the same county have had the widest distribution and are the best known of the Georgia granites outside of the State. From the time of their first opening, prior to the civil war, to within the last few years the quarrying of stone in these two areas formed practically the whole granite industry in Georgia. These are the largest granite quarries in Georgia and they yield a much larger output than any other areas in the State.

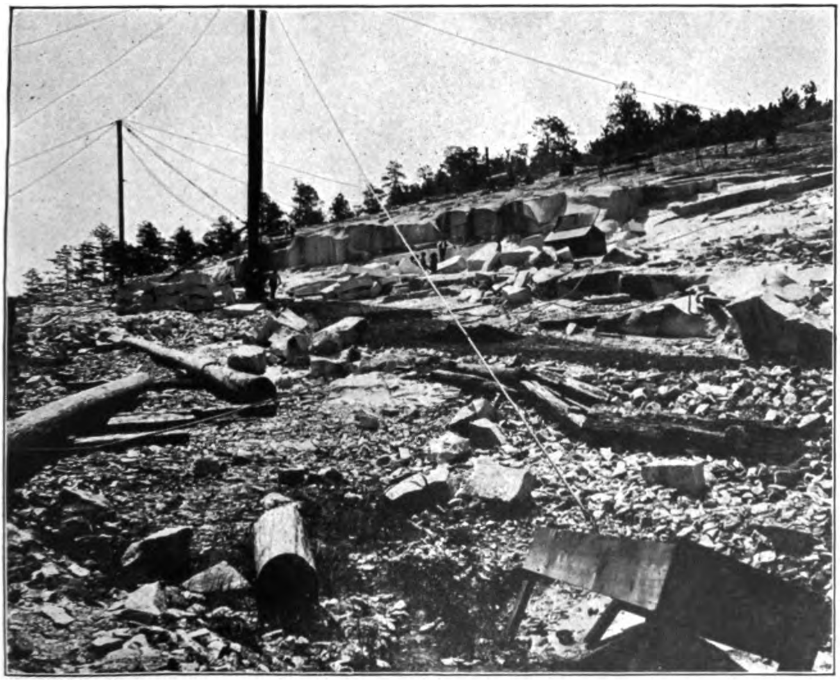
Numerous quarries yielding an excellent light-gray granite are worked along the western and southern flanks of the ridge. (See Pl. XXV, *B*.) The stone has been used most extensively for general building purposes, and almost as largely for street material in the form of blocks and curbing. Its very light color makes it undesirable for monument stock. It has been marketed in the principal towns and cities in the South and West.

The doming mass is apparently formed of sheets of varying thicknesses, with no visible lines of separation except at the surface, where the granite has been subjected to weathering. The sheets conform in general to the present surface of the boss. They are cut by two sets of vertical joints, which, in connection with the slope, afford superior facilities for easy quarrying. The vertical joints are widely spaced and intersect at approximately right angles, but jointing is not a conspicuous feature. Slickensides on the joint surfaces indicate subsequent movement. The rock is further cut by pegmatite dikes, which vary in width from a fraction of an inch to 18 inches. In addition to the coarsely crystallized feldspar and quartz composing these dikes, mica, tourmaline, and garnet occur, in places concentrated along the central portion of the dike rather than distributed through the light-colored quartz-feldspar portions. Several aplite dikes less than 6 inches in width, banded with pegmatite, are exposed in the quarries on the northwest side of the mountain. The table of analyses (p. 235) shows that the aplite of the Stone Mountain boss contains equal potash and soda.

Every facility in the way of modern equipment for work, such as engines, boilers, steam drills, and other appliances and machinery, is in use at Stone Mountain. About 8 miles of railway are operated from the main line of the Georgia Railroad at Stone Mountain station to and around the base of the ridge. The equipment is probably equal in all essentials to that of the larger quarries in the East, and renders the company abundantly able to handle stone of any desired



A. STONE MOUNTAIN, A GRANITE DOME, DEKALB COUNTY, GA.



B. STONE MOUNTAIN QUARRIES, STONE MOUNTAIN, DEKALB COUNTY, GA.

dimensions and shape. As opened in 1893, the Stone Mountain quarries were capable of yielding 25,000 paving blocks a day. At present this can be increased to any desired output.

ISOLATED AREAS OF EVEN-GRAINED GRANITE.

Putnam, Spaulding, Warren, and Wilkes counties contain even-granular granites which belong to one or the other type of biotite granites described above. These are of future commercial importance and should therefore be noted. In each place a little of the stone has been quarried for local purposes. The granites are closely similar in mineral and chemical composition and range from light to dark blue-gray in color and from medium-coarse to fine grained in texture. Muscovite is sparingly present in the granite of Spaulding and Putnam counties. The location and general properties of these granites may be briefly summarized as follows:

Just beyond the northern limits of Griffin, Spaulding County, several very small openings are made in a biotite granite of light-gray color and medium-coarse grain. A little muscovite occurs in the rock, a chemical analysis of which is given below.

The *Linch quarry,* 4 miles west of Eatonton, Putnam County, is opened in a biotite granite of dark blue-gray color and even, fine grain. Scant muscovite is associated with the biotite. The granite is susceptible of a high polish and is entirely suited for monumental stock. It resembles the dark blue-gray granite of the Oglesby-Lexington area. A chemical analysis of the stone is given below.

Analyses of granite from Putnam and Spaulding counties, Ga.

Constituents.	Putnam County.	Spaulding County.
Silica (SiO_2)	69.34	69.07
Alumina (Al_2O_3)	17.01	16.56
Iron oxide (Fe_2O_3)	1.74	1.37
Magnesia (MgO)	.61	.76
Lime (CaO)	2.77	1.83
Soda (Na_2O)	4.69	4.66
Potash (K_2O)	4.54	5.02
Ignition	.26	.92

The specific gravity is 2.701 and the percentage of absorption is 0.060.

In Warren County, 2 miles southeast and 7½ miles east of Warrenton, are large areas of biotite granite of light-gray to dark blue-gray color and fine grain. This area extends eastward into McDuffie County.

Two miles south of Washington, Wilkes County, a biotite granite of medium-gray color and medium-coarse grain has been opened. A schistose structure is indicated in places.

PORPHYRITIC GRANITES.

GENERAL STATEMENT.

Associated with the even-granular granites within the Georgia Piedmont region are a number of coarse-textured porphyritic granites. The distribution of the principal areas of porphyritic granite is shown on the accompanying map (fig. 20.) These are (A) the area in Campbell, Coweta, and Fayette counties; (B) the Pike County area; (C) the Fulton County area; (D) the Brinkley Place–Holders Mill area; (E) the Sparta area; (F) the Milledgeville area; (G) the Greene County area; and (H) the Columbia County area.

Except in the Sparta area, the porphyritic granite has been only sparingly quarried, and then to supply a strictly local demand. The areas in Greene and Columbia counties are too remote from lines of transportation to be of commercial importance. The granite exposures are in the nature of bowlders and flat-surfaced or low doming masses, usually of large size.

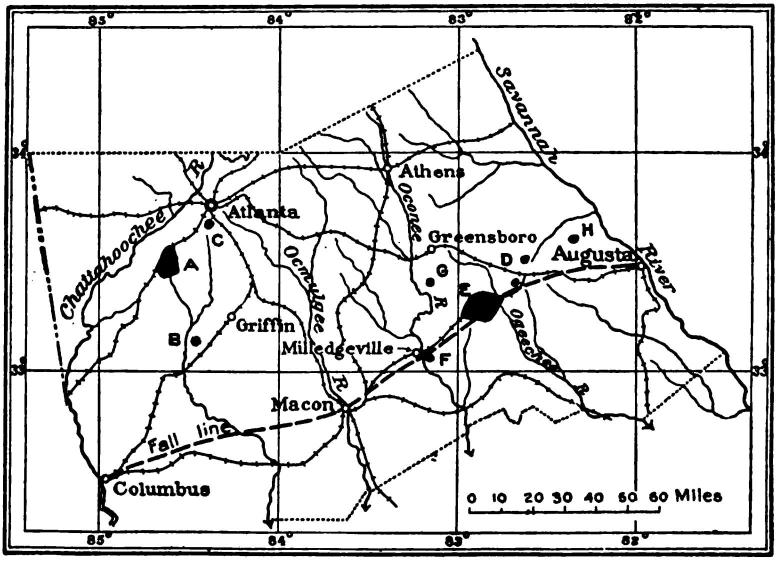


FIGURE 20.—Map of Piedmont Georgia, showing areas of porphyritic granite.

Certain general features are common to all the porphyritic granites, although the rocks are strongly contrasted in some of the areas. With one exception they are massive, without, as a rule, visible evidence of primary or secondary foliated structure. The exception is in the Brinkley Place–Holders Mill area, where the rock has a pronounced schistose structure, induced by pressure metamorphism. The porphyritic granites are prevailingly of light to dark gray color, according to the amount of biotite present, and of coarse grain.

The same textural and structural characteristics and relationships are generally developed in each of the areas of porphyritic granite. Gradation from one rock facies (porphyritic) into the other (even granular) was not sharply defined in every area, owing, perhaps, to a lack of sufficient exposures, but it could be easily traced in many of them.

MICROSCOPIC CHARACTERS.

Microscopically, the rocks are as nearly identical as it is possible for rocks of separate areas to be. They all contain the same minerals, both essential and accessory, in nearly the same proportions. They are composed of admixtures of the feldspars and quartz, in which lie stout plates of biotite.

The groundmass is a coarse-grained biotite granite, the essential constituents of which measure 3 to 8 millimeters. Microcline is subject to more variation in amount than in the even-granular granites described above, and plagioclase is slightly increased. The plagioclase shows roughly lath-shaped outlines and as a rule the extinction angles indicate an acidic feldspar near oligoclase. The ratio of lime to soda in the analyses given on page 240 corroborates the inference. Orthoclase shows microperthitic intergrowths with a second feldspar, probably albite. Intergrowths of quartz and feldspar, present in all the thin sections, afford evidence of simultaneous crystallization of a part of the feldspar and quartz. Micropoikilitic feldspars, from inclusions of quartz principally, are abundant. Biotite, intergrown with occasional foils of muscovite, is the chief accessory and varies somewhat in quantity for the individual areas. Apatite, zircon, and magnetite occur as accessories. A little chlorite, epidote, and light-colored mica are present as constant secondary products from the alteration of the biotite and feldspars. Many of the thin sections show the effects of pressure metamorphism in the nature of crushing, lines of fracture, and undulatory extinction common to some of the larger quartz-feldspar individuals.

The potash feldspars are the only porphyritically developed minerals. They are usually opaque and white in color, but pink tints are common. They vary from 10 to 15 millimeters in length and from 5 to 10 millimeters in width, and show further variation from allotriomorphic (without crystal faces) to idiomorphic (with crystal faces) individuals. The idiomorphic type prevails and is flat tabular, parallel to the clinopinacoid, with (001) and (101) cleavages well developed. The feldspars display the usual habit of simple Carlsbad twins. As a rule the phenocrysts are very conspicuous and are readily differentiated from the groundmass feldspar; although in Campbell, Coweta, and Fayette counties the phenocrysts and a portion of the groundmass feldspars seemingly grade into each other. The phenocrysts invariably contain inclusions of all the groundmass minerals, and this, with other evidence, indicates simultaneous growth with the interstitial components. The included biotite plates are macroscopic in size and in many places the included mica is as large as the same groundmass mineral. The inclusions are distributed through the phenocrysts without regard to definite arrangement. Analyses of feldspar phenocrysts from two of the Georgia areas are given below (Nos. 9 and 10).

CHEMICAL COMPOSITION.

The marked uniformity in the mineral composition of the various porphyritic granites from the widely separated areas suggests similar uniformity in chemical composition. The usual amount of free quartz common to this class of rocks and the abundance of potash feldspar, with increased amounts of plagioclase and proportionally small amounts of accessory minerals, indicate a normal percentage of silica and lime, an increased percentage of alkalies, and comparatively small amounts of iron and magnesium oxides. These inferences are well shown in the analyses given below. Attention is called to the prevailingly high percentage of soda shown. In nearly half of the analyses the soda is slightly in excess of the potash and in the remainder it nearly equals or is but slightly less than the potash, a proportion which allies these rocks, like the even-granular granites, with quartz monzonites. This high range in soda is traceable primarily to the large amount of acidic plagioclase; second, to the microperthitic intergrowths of acidic plagioclase with the potash feldspars present in the rocks; and last, to the partial replacement of potash by soda in the straight potash feldspar (analyses 9 and 10). A comparison of these analyses with those of the even-granular granites (pp. 220, 225, 229, 235, 237) shows very close agreement.

Analyses of the Georgia porphyritic granites.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	70.90	70.88	70.24	69.77	69.48	69.37	69.17	69.13	64.64	64.40
Al_2O_3[a]	15.86	15.86	16.78	17.05	16.64	16.99	16.47	17.14	19.64	18.97
Fe_2O_3[b]	1.37	1.77	1.46	1.60	1.84	1.99	1.23	1.52	.37	.37
MgO	.02	.93	.76	.99	.29	.84	.61	.79	Tr.	Tr.
CaO	2.15	1.79	2.00	2.21	2.32	2.93	2.02	1.85	.67	.59
K_2O	4.62	4.64	5.03	4.08	4.49	4.54	4.41	5.49	10.00	11.40
Na_2O	5.05	3.94	3.70	3.97	4.74	3.44	4.89	4.06	3.06	3.60
Ignition	.50	.49	.50	.44	.46	.55	1.06	.52	.22	.19
	100.47	100.30	100.47	100.11	100.26	99.75	99.85	100.50	98.60	99.52

[a] Contains traces of P_2O_5 and ZrO_2.

[b] All iron was determined as Fe_2O_3.

1. Georgia Quincy Granite Company's quarry, near Sparta, Hancock County.
2. McElwaney place, near Line Creek, Fayette County.
3. Flat (Cedar) Rock, 9 miles west of Zebulon, Pike County.
4. Heggie Rock, 3 miles east of Appling, Columbia County.
5. Sparta quarry, Hancock County.
6. Calloway place, 3 miles southeast of Milledgeville, Baldwin County.
7. Moseley quarry, 6 miles south of Atlanta, Fulton County.
8. Porphyritic granite area, 10 miles south of Greensboro, Greene County.
9. Feldspar phenocrysts from Heggie Rock, Columbia County.
10. Feldspar phenocrysts from McCollum place, Coweta County.

PHYSICAL TESTS.

Tests to determine specific gravity, ratio of absorption, weight per cubic foot, and number of cubic feet of stone contained in 2,000 pounds were made on the porphyritic granites as follows:

Physical tests of porphyritic granites.

Quarry.	Specific gravity.	Ratio of absorption.	Weight per cubic foot (pounds).	Cubic feet of stone in 2,000 pounds.
Charley Rocker, Hancock County	2.687	0.037	167.93	11.9
Georgia Quincy Granite Company	2.664	....	166.50	12.0
Mallally, Hancock County	....	.049	....	....
Heggie Rock, Columbia County	2.674	....	166.87	11.9
McElwaney, Fayette County	2.659	....	166.18	12.0

DESCRIPTION OF INDIVIDUAL AREAS.

CAMPBELL, COWETA, AND FAYETTE COUNTIES.

The area occupying contiguous portions of Campbell, Coweta, and Fayette counties, marked A on the accompanying map (fig. 20), lies 30 miles southwest of Atlanta. The outcrops are usually small and in the nature of bowlder and flat-surfaced masses. The exposures are most numerous in the vicinity of Palmetto and Coweta, stations on the Atlanta and West Point Railroad, and near Line Creek, in Fayette County. Specimens of the porphyritic granite collected from the outcrop near Line Creek are somewhat lighter in color than similar ones from the Palmetto and Coweta areas. The ratio of quartz to biotite in the Line Creek outcrop is visibly greater than in the exposures in Campbell and Coweta counties. The rock, however, is generally rather uniform over the entire area. Several good contacts of the partly decayed porphyritic granite and mica schist are exposed along the wagon roads and in the cuts of the railroad traversing the area. The field relations of the two rocks indicate that the porphyritic granite is the younger rock, intruded into the overlying schist and exposed subsequently by erosion.

The granite is a porphyritic granite of medium-light to dark gray color and coarse grain. Its extreme coarseness renders the porphyritic texture less pronounced in this than in the finer-grained porphyritic granites. The porphyritically developed mineral (feldspar) grades imperceptibly from very large, irregular, locally stout, tabular phenocrysts into the smaller feldspars of the groundmass, making it difficult usually to distinguish between groundmass and phenocryst feldspar.

The feldspar phenocrysts vary from extremely irregular cleavable grains, anhedra 30 by 30 millimeters in size, to roughly idiomorphic crystals, tabular, parallel to the clinopinacoid (010), and twinned on the Carlsbad law. Abundant inclusions of large irregular plates of biotite are readily visible to the unaided eye, in all the phenocrysts. The phenocrysts are prevailingly allotriomorphic and differ in this respect from those of the other areas described below. The feldspars are white in color, as a rule partly cloudy or opaque rather than limpid in appearance. The porphyritically developed minerals are composed of both orthoclase, with microperthitic structure, and microcline usually inclosing inequidimensional grains of quartz, feldspar, and biotite, without orientation. The more basic inclusions, accessory apatite and zircon, are also contained in the phenocrysts.

A thin section of one of the feldspar phenocrysts from the Coweta portion of the area shows the characteristic microcline structure and contains abundant inclusions of irregularly bounded crystals of feldspar, quartz, and biotite; several rounded disks or ovals of intergrowths of quartz and feldspar; and prismatic needle-like inclusions of apatite and zircon. A chemical analysis of fragments of carefully selected phenocrysts from hand specimens of the Coweta outcrops of the rock is given on page 240 (No. 10).

The porphyritic granites from Anson and Richmond counties and those from Mount Monroe, Iredell County, N. C., closely resemble in color and texture the porphyritic granite of Campbell, Coweta, and Fayette counties in Georgia. The phenocrysts in the North Carolina granite are usually without crystal boundaries (allotriomorphic) and as a rule are large and contain numerous plates of included biotite. A similar rock, though darker colored because of the larger amount of biotite present, occurs in Aiken County, S. C. The porphyritic feldspars in the Aiken County granite present the same characteristics as the phenocrysts of the Georgia and North Carolina porphyritic granites.

The granite of the Georgia locality has been opened in a number of places where a little stone has been quarried to supply a purely local demand.

PIKE COUNTY.

The Pike County granite area, marked B on the map (fig. 20), includes 50 acres or more of exposed flat-surfaced rock in the northwestern part of the county. The porphyritic facies of the rock gradually passes into the even-textured granite. Only a small proportion of this area, however, shows the porphyritic texture. The rock is a biotite granite of medium-gray color and medium grain. It varies from even granular to porphyritic in texture, and shows in places a partial gneissoid structure. The phenocrysts consist of the potash feldspars, orthoclase and microcline, measuring 10 to 30 millimeters long and 5 to 10 millimeters broad, flat tabular, and parallel to the clinopinacoid (010). Carlsbad twinning is common. Inclusions of biotite as large as that occurring in the groundmass are very abundant in the phenocrysts, which contain, in addition to the biotite, microscopic inclusions of irregularly bounded crystals of the interstitial quartz and feldspar.

The granite has not been quarried, except that now and then a surface "raise" is made, and some stone is obtained for chimneys and foundations for houses in the immediate neighborhood. The stone can be easily quarried, and is of good quality.

FULTON COUNTY.

The porphyritic granite of the Fulton County area, marked C on the map (fig. 20), is exposed in bowlder form over a large territory 6 miles south of Atlanta, in the extreme southern part of the county. The gradation from the interior porphyritic facies, peripherally, into an even-textured granite of the same color and texture and having the same mineral and chemical composition is more gradual and more strikingly shown in this than in any of the areas previously described.

Near the center of the granite mass the phenocrysts compose more than 50 per cent of the rock and near the center the phenocrysts usually show crystal outline (idiomorphic), but in the transition zone of the granite mass they are allotriomorphic (without crystal outline).

The granite consists of a medium-coarse groundmass of quartz, the potash feldspars (orthoclase and microcline), numerous laths of twinned plagioclase, biotite, and some muscovite, in which are embedded large potash-feldspar phenocrysts. Accessory apatite, magnetite, and zircon and the alteration products chlorite, kaolin, and light-colored mica are noted. Some of the feldspars and biotite are considerably altered. Microcline and orthoclase are porphyritically developed and measure 15 to 50 millimeters in length. The phenocrysts possessing idiomorphism (crystal outline) usually display the Carlsbad twinning and are elongated in the clinopinacoidal direction.

A thin section of one of the phenocrysts showed the characteristic microcline structure and numerous inclusions of quartz, biotite, and the groundmass feldspars, which measure as much as 1 millimeter. Prismatic crystals of apatite and zircon, as inclusions in both the phenocrysts and the included groundmass feldspars of the porphyritic crystals, are numerous. The zircon crystals are in places grouped in threes, much after the manner of penetration twins.

Quarrying in this area has been confined to the working up of a few large bowlders, but the accessibility and good qualities of the stone should give it future importance.

WARREN COUNTY.

Two somewhat extensive outcrops of foliated porphyritic biotite granite occur in the middle portion of Warren County, approximately 10 miles from each other in an almost east-west direction. These are known as the Holders Mill and Brinkley Place granite masses, and are marked D on the map (fig. 20).

The rock has a pronounced secondary foliated structure. The quartz and feldspar crystals are drawn out and inclosed between the biotite layers, forming in places distinct augen of the two light-colored minerals. The rock contains abundant black biotite plates arranged along somewhat parallel lines. The quartz and feldspar grains are greatly squeezed and mashed, and are more or less drawn out in directions parallel with the biotite layers, as a result of pressure metamorphism. The foliated structure is derived or secondary and not primary.

The feldspar phenocrysts are composed principally of microperthitic orthoclase, with some microcline 15 to 20 millimeters long, are opaque white to pink in color, contain numerous inclusions of biotite plates, and exhibit the usual habit of Carlsbad twins. They are prevailingly irregular in crystal outline and badly fractured from subsequent intense metamorphism. They are embedded in a coarse-grained groundmass of quartz, feldspar, and biotite. The groundmass feldspathic constituent consists of the potash feldspars, with microperthitic structure, and some laths of plagioclase near oligoclase. The large feldspar individuals (phenocrysts) contain inclusions of irregularly bounded crystals of quartz, biotite, and other feldspar species. These inclusions are usually round or oval in outline. Peripheral shattering from pressure effects of the larger feldspar and quartz crystals is pronounced. Intergrowths of quartz and feldspar are common. Biotite occurs as grouped shreds and plates altered to chlorite and here and there to epidote. A few scattered grains of magnetite are observed.

Still a third exposure of granitoid rock showing a pronounced porphyritic texture in places lies 6 to 8 miles south of the Brinkley Place–Holders Mill area. It differs greatly from the granite of that area in having a less strongly marked and finer-grained porphyritic texture, in containing less biotite, and in being massive instead of foliated in structure; it also contains a larger proportion of plagioclase and a smaller percentage of microcline. This area is entirely undeveloped.

HANCOCK COUNTY.

A coarse-grained porphyritic granite outcrops a quarter of a mile east of Sparta depot, Hancock County, and the exposures are more or less continuous from this point for 11 miles in a northeast direction along the Georgia Railroad, extending from Sparta to Mayfield station. This area, marked E on the map (fig. 20), lies near the passage of the crystalline rocks beneath the Coastal Plain sands and clays (the "fall line") and is the only producing area of porphyritic granite in Georgia. It is elliptical in shape, with its longer diameter trending northeast and southwest for 11 miles. The granite outcrops as bowlder and flat-surfaced masses, covering as much as 4 to 5 acres in a single exposure. The area is traversed by the Macon branch of the Georgia Railroad, which affords ample facilities for shipping.

The rock is generally porphyritic, grading in many localities into a nonporphyritic, even-grained granite of the same mineral and chemical composition. In several places the porphyritic texture almost wholly disappears and the rock grades into a coarse-grained biotite granite. In a number of quarries the rock shows in places a somewhat pronounced gneissoid structure. Joints are not conspicuous in any of the quarries and are everywhere widely spaced. Pegmatites cut the granite in several of the quarries.

The rock is prevailingly a coarse-grained, medium-gray porphyritic biotite granite. The phenocrysts are composed of the potash feldspars, having a pronounced pinkish cast, which appears in the thin sections. They are flat tabular in crystal form, averaging 20 millimeters in length parallel to the clinopinacoid (010). Carlsbad twins are common. The phenocrysts are further characterized by numerous inclusions of the principal groundmass minerals.

The porphyritic feldspars are embedded in a coarse-grained groundmass of quartz, potash and soda-lime feldspars, and biotite, with some accessory muscovite, chlorite, apatite, zircon, epidote, and scattered grains of magnetite. Microperthitic structures are common to the potash feldspars. Intergrowths of quartz and feldspar are less frequently observed than in some other areas. The rock of the Hancock County area differs from that of Campbell, Coweta, and Fayette counties in containing less biotite and hence being lighter in color, and in that the phenocrysts are idiomorphic instead of allotriomorphic and are usually of a pinkish cast rather than white. Microcline is likewise variable for the two areas in thin sections of the rock examined from various places.

Like the rock in the Campbell-Fayette area, the porphyritic granite of Sparta is surrounded on all sides by mica schist; but the great depth of residual decay of the granite and schist prevents exposures of the contact between the two. The field relations indicate, as in the other area, that the granite is the younger rock, intrusive into the then overlying schist.

The chemical composition of the granite from this area is shown in analyses 1 and 5, page 240. The percentage of absorption is small, as indicated on page 241. The granite has had an extensive use in Georgia and several of the adjoining States, principally for street purposes, as in Belgian blocks and curbing. It has been used to some extent as a building stone and occasionally for monuments.

A number of quarries have been worked somewhat extensively within several miles northeast of Sparta. These are listed below.

Quarries in the Sparta area, Hancock County, Ga.

	Miles northeast of Sparta.
Charley Rocker	3½
Georgia Quincy Granite Company	2
Mackin	1¾
Mallally	¾
Old Rocker	3¼

The *Charley Rocker quarry*, about 3½ miles northeast of Sparta and three-quarters of a mile north of the Georgia Railroad, is opened in a flat-surfaced exposure of the granite. It has been worked to a depth of less than 20 feet. The product is used principally in the form of blocks for street paving. The rock is a porphyritic biotite granite of light gray color and coarse grain. A chemical analysis of the granite is here given for reference:

Analysis of granite from Charley Rocker quarry, near Sparta, Ga.

Silica (SiO_2)	67.62
Alumina (Al_2O_3)	16.29
Iron oxide (Fe_2O_3)	2.31
Magnesia (MgO)	.78
Lime (CaO)	2.37
Soda (Na_2O)	5.42
Potash (K_2O)	4.58
Ignition	.32

The specific gravity is 2.687, and the percentage of absorption is 0.037.

The *Georgia Quincy Granite Company's quarry* is half a mile south of the Georgia Railroad and about 2 miles northeast of Sparta, in a large flat-surfaced exposure of granite. Three acres or more have been stripped. The product is used principally for street work in the form of blocks and curbing and to a minor extent in buildings. The rock is a porphyritic biotite granite of medium-gray color and coarse grain. A gneissoid structure is discernible in places. Vertical joints of wide spacing and a few pegmatite dikes several inches wide intersect the granite. The joint surfaces are slickensided from subsequent movement in the granite mass. A chemical analysis of the granite is given on page 240 (No. 1); and the results of physical tests on page 241.

The *Mackin (Sparta) quarry*, a quarter of a mile north of the Georgia Railroad and about 1¾ miles northeast of Sparta, is a small opening. The rock is a porphyritic biotite granite of medium-gray color and coarse grain. The opening exposes a 9-foot dike of dark-gray, fine, even-grained granite penetrating the porphyritic granite.

The *Mallally* (*Sparta*) *quarry*, a quarter of a mile north of the Georgia Railroad and about three-quarters of a mile northeast of Sparta, is opened in a flat-surfaced outcrop. It has been worked to a depth of 25 feet in places. The rock is a porphyritic biotite granite of medium-gray color and coarse grain. It is difficult to distinguish in hand specimens from the Georgia Quincy Granite Company's rock. A chemical analysis of the granite is given on page 240 (No. 5); and the results of physical tests on page 241. The rock is cut by an east-west set of vertical joints, and by a dike several feet wide of very fine textured, dark blue-gray biotite granite. It contains a few dark-colored segregations (knots).

The *Old Rocker quarry*, one of the first quarries opened in the area, is about a quarter of a mile northwest of the Charley Rocker quarry, described above. The granite is exposed in ledge form over several acres of ground. Considerable quarrying has been done and the product was used as blocks and curbing for street work. The rock is a biotite granite of light-gray color and even, coarse grain. It differs in texture from the granite of the other quarries in the area in being even granular instead of porphyritic and in containing less of the black mica (biotite).

BALDWIN COUNTY.

Large bowlder outcrops of coarse-grained porphyritic granite occur 3 miles southeast of Milledgeville, the county seat of Baldwin County. Like the rock of the Hancock County area, the Baldwin County porphyritic granite mass is located near the line of contact between the Piedmont crystalline rocks and the Coastal Plain sediments (area marked F on the map, fig. 20).

A part of the granite used in the construction of the old state capitol at Milledgeville, now the State Normal and Industrial College, was quarried from this area. No regular quarries have been opened and no recent quarrying has been done.

Hand specimens of the granite from Baldwin County are indistinguishable from similar specimens of the Columbia County porphyritic mass, described below. The rock is a very coarse grained porphyritic granite, composed of an aggregate of interlocking quartz and feldspar—orthoclase with microperthitic structure, microcline, and plagioclase—with intergrown shreds of biotite. It varies in color from medium to dark gray. Both microcline and orthoclase occur in the groundmass and as porphyritically developed minerals. The larger phenocrysts are 30 to 40 millimeters long and 5 to 10 millimeters broad. They are prevailingly idiomorphic (with crystal faces) in form, flat tabular parallel to the clinopinacoid (010), and commonly twinned on the Carlsbad law. Abundant inclusions of black biotite folia are plainly visible to the unaided eye in the feldspar phenocrysts, and numerous additional irregularly bounded quartz and feldspar grains without definite orientation are shown by the microscope.

The groundmass is composed of an abundance of white, opaque feldspars, dark-colored smoky quartz, and biotite plates measuring 2 to 5 millimeters in diameter. The accessories are apatite, zircon, and scattered grains of magnetite, with some secondary light-colored mica, chlorite, and epidote derived from the alteration of the feldspars and biotite. Bent and curved filaments of rutile are abundant in the larger quartz grains. The effects of slight pressure metamorphism are evident in the lines of fracture and undulous extinction common to the larger quartz and feldspar individuals.

GREENE COUNTY.

The Greene County porphyritic granite area, marked G in figure 20, includes at least 100 acres in the main outcrop, located 10 miles south of Greensboro, in the southern part of the county. The main central exposure is in the form of a low, flat-doming mass with a roughened and irregular surface, partly covered with a thick growth of cedars.

An even-granular granite of medium-coarse grain outcrops in bowlder form 3 miles south of Greensboro, and is continuous along the public highway from this point to the main porphyritic mass. The even-granular texture grades interiorly into the typical porphyritic texture. The even-granular granite apparently varies in mineral composition from place to place along the north-south section. A zone 2½ miles north of the porphyritic area shows absence of all trace of porphyritic texture, but is a medium-grained biotite granite agreeing, microscopically, in mineral and in chemical composition with the porphyritic granite. Five miles north of the central porphyritic mass are outcrops of a coarse but close, compact-grained granite, containing only a very small amount of biotite. The feldspars show pronounced pink and greenish tints. About 4 miles south of Greensboro, on the north side of Beaver Dam Creek, is an outcrop of practically the same granite. The quartz is decidedly dark in color and of the smoky variety; the feldspars are flesh colored, and the rock contains but little mica.

The porphyritic facies of the rock consists of a coarse-grained light-gray groundmass of quartz, feldspar, and biotite, in which are embedded large, flat-tabular feldspar phenocrysts. The porphyritic feldspars average 30 to 50 millimeters in length and 10 to 15 millimeters in breadth, and indicate the usual elongation parallel to the clinopinacoid (010) and Carlsbad twinning. The phenocrysts are deep pink to perfectly white in color and are mostly cloudy and opaque in appearance.

A thin section of one of the phenocrysts under the microscope showed the feldspar variety microperthitic orthoclase. The microscope further revealed abundant inclusions of fairly large grains of feldspar, twinned in several places after the albite and Carlsbad laws, and of quartz and biotite having partial orientation with the (010) cleavage. As a rule, however, the inclusions are not oriented. The biotite inclusions are sufficiently large to be visible to the unaided eye.

The ratio of phenocrysts to groundmass is variable, the probable extremes being 1 to 1 and 2 to 1, with all gradations between. The individual mineral grains range from a few millimeters to 5 or 6 millimeters in size. The arrangement of phenocrysts in some small portions of the mass is suggestive of fluxion structure.

The potash feldspars, orthoclase, and microcline are the porphyritically developed minerals. The orthoclase contains numerous microperthitic structures. Plagioclase is abundant. Small rounded disks or ovals of intergrown quartz and feldspar are common. The larger feldspar and quartz crystals indicate slight peripheral shattering in some of the thin sections.

The biotite is considerably altered to chlorite and some epidote, and some of it carries inclusions. Scattered grains of magnetite and prismatic inclusions of apatite and zircon are present.

Remoteness from lines of transportation has precluded development of this area. A few stones have been stripped from time to time from several of the surface ledges and used in the construction of some of the county homes.

COLUMBIA COUNTY.

The Columbia County area, marked H on figure 20, lies near the fall line (the contact between the Piedmont crystalline rocks and the Coastal Plain sediments), a short distance west of the South Carolina boundary.

About 1¾ miles east of Appling, the county seat of Columbia County is an outcrop of coarse-grained porphyritic granite. The feldspars are slightly pink in color, with a somewhat greenish cast in places. The phenocrysts measure 20 to 35 millimeters in length and 5 to 15 millimeters in breadth, and commonly show the contact type of Carlsbad twins. The rock is composed of a coarse-grained groundmass of potash and plagioclase feldspars (orthoclase predominating) and quartz, with biotite and scattered large plates of muscovite. The phenocrysts consist of large tabular microperthitic orthoclase. The quartz grains are badly fractured. Plagioclase feldspar is more abundant in this than in many of the other granite areas. Intergrowths of quartz and feldspar are sparingly present. The large feldspar phenocrysts contain abundant inclusions of the groundmass minerals, especially biotite and plagioclase.

The main porphyritic granite body is 1¼ miles farther east, outcropping as a large doming mass. The porphyritic facies is readily traceable peripherally into an even-granular granite of medium-coarse texture. The even-granular facies of the rock is best exposed along the public highway 3 miles slightly east of south from Appling. Hand specimens of the rock from the two exposures can not be distinguished from each other. The porphyritic feldspars in the principal exposure show the same microscopic tendencies as in the other areas.

A thin section of one of the phenocrysts from the main outcrop showed the characteristic microcline structure, with numerous inclusions of irregular grains of all the groundmass minerals. A chemical analysis of carefully selected fragments of phenocrysts from this rock yielded the results given on page 240 (No. 10).

The phenocrysts are embedded in a coarse-grained groundmass of flesh-colored feldspars having a slight greenish cast, somewhat dark, smoky quartz, and biotite. The porphyritic feldspar crystals make up nearly half of the rock. The feldspars are white and opaque rather than pink in color over the greater part of the exposure. In the hand specimens this rock very closely resembles that from Greene County. Here, as in the areas described above, the feldspathic constituent consists of potash and plagioclase feldspars in nearly equal amounts. The porphyritic feldspars are chiefly orthoclase with some microcline, carrying inclusions of all the groundmass minerals. The included biotite shreds are visible microscopically. Some of the largest plagioclase inclusions in the orthoclase phenocrysts carry, in turn, microscopic inclusions of quartz and other groundmass minerals. Twinning according to the Carlsbad and albite laws among the included feldspar species is commonly observed. The biotite is partly altered to chlorite and epidote. Muscovite is sparingly present, intergrown with biotite. Accessory magnetite and apatite occur.

Like that of Greene County, the Columbia County area is entirely undeveloped, because of its remoteness from lines of railroad.

GRANITE GNEISSES.

INTRODUCTORY STATEMENT.

A major part of the granitic rocks in the Piedmont region of Georgia are gneisses, both light-colored (acidic) and dark-colored (basic) rocks. The light-colored or acidic gneisses closely resemble the massive granites; the dark-colored or basic gneisses usually carry much hornblende in place of biotite and a preponderance of plagioclase over the potash feldspars. These features suggest that the basic gneisses are the banded equivalents of the eruptive basic rocks, gabbro and diorite, from which they have probably been derived. They assume a porphyritic facies in some localities.

Extensive areas of light-colored gneiss of granitic composition occur in the Georgia Piedmont region, this type being one of the most important in the plateau complex. The granitic gneisses vary from medium to coarse textured rocks, having a pronounced banded or schistose structure. The planes of schistosity vary from moderately irregular to highly contorted lines and the banding is exceedingly irregular, ranging from very thin to relatively thick layers.

The granite gneisses are closely related, genetically, to the massive granites, from which they differ only in the banded structure, secondarily induced by pressure metamorphism. The two types are essentially alike in mineral and chemical composition. The minerals occurring in one are invariably present in the other. Moreover, the minerals most abundant in one are predominant in the other. Like the massive granites the acidic gneisses are biotite-bearing rocks. Muscovite is a general associate of the biotite but is subordinate in amount. Hornblende does not occur. For these reasons the acidic gneisses are believed to have been derived from the massive granites, and are therefore designated granite gneisses. Probably there are gneisses of sedimentary origin in the Georgia Piedmont region, but the areas of gneiss studied and described in this report afford no evidence of such rocks.

There are in Georgia two principal areas of granite gneiss, which, though widely separated, are essentially identical in all respects. These are the Lithonia-Conyers-Lawrenceville area (fig. 19) and the Odessa-Mountville area. Of these only the first has been extensively developed. The stone from it has been extensively quarried and shipped beyond the limits of the State and is probably as well known both in and out of the State as the famous granite of Stone Mountain.

Among the larger and more important areas of undeveloped granite gneiss are Flat Rock, in Heard County; Flat Shoals, in Meriwether County; Flat Rock, in Coweta County; the Covington area, in Newton County; and the Athens area, in Clarke County.

CHEMICAL COMPOSITION.

The chemical composition of the granite gneisses is well brought out in the analyses below, which were made by the writer in the Georgia Survey laboratory. A comparison of these analyses with those of the massive even-granular granites on page 211 will indicate strikingly close similarity. The gneisses average slightly higher in silica and somewhat lower in alumina and lime than the granites.

Analyses of granite gneisses from Georgia.

	1.	2.	3.	4.	5.	6.	7.	8.
Silica (SiO_2)	76.37	76.00	75.89	75.45	74.06	71.20	69.51	68.89
Alumina (Al_2O_3)	13.31	13.11	14.02	13.71	14.22	15.46	16.32	16.47
Iron oxide (Fe_2O_3)	1.21	.92	.71	.92	1.09	1.17	2.38	2.34
Magnesia (MgO)	.10	.27	.12	.18	.12	.38	1.28	.40
Lime (CaO)	1.13	1.06	.70	.94	1.09	1.36	1.84	1.63
Soda (Na_2O)	4.02	3.88	3.64	3.87	3.97	4.96	3.82	4.38
Potash (K_2O)	3.68	4.69	5.56	4.30	4.89	5.30	3.47	4.15
Ignition	.20	.31	.28	.40	.27	.52	1.11	.32
Specific gravity	2.642	2.686	2.642	2.643	....	....	....	....

1. Contorted biotite granite gneiss, Odessa quarry, Meriwether County.
2. Contorted biotite granite gneiss, Crossley quarry, near Lithonia, Dekalb County.
3. Contorted biotite granite gneiss, Snell quarry, Snellville, Gwinnett County.
4. Contorted biotite granite gneiss, Tilly quarry, Rockdale County.
5. Contorted biotite granite gneiss, average of quarries near Lithonia, Dekalb County.
6. Biotite granite gneiss, Freeman quarry, near Covington, Newton County.
7. Biotite granite gneiss, Athens, Clarke County.
8. Biotite granite gneiss, McElvaney Shoals, Gwinnett County.

PHYSICAL TESTS.

The results of tests made on the Georgia gneisses to determine specific gravity, ratio of absorption, weight per cubic foot, and number of cubic feet of stone in 2,000 pounds are tabulated below:

Physical tests of granite gneisses from Georgia.

Quarry.	Specific gravity.	Ratio of absorption.	Weight per cubic foot (pounds).	Cubic feet of stone in 2,000 pounds.
Odessa, Meriwether County	2.642	0.056	165.12	12.1
Snell, Gwinnett County	2.642	.075	165.12	12.1
Tilly, Rockdale County	2.643	....	165.18	12.1
Lithonia, Dekalb County	2.686	.052	167.90	11.9
Flat Rock, Heard County	2.648	....	165.50	12.0
Arabia Mountain, Lithonia	....	.050	....	....

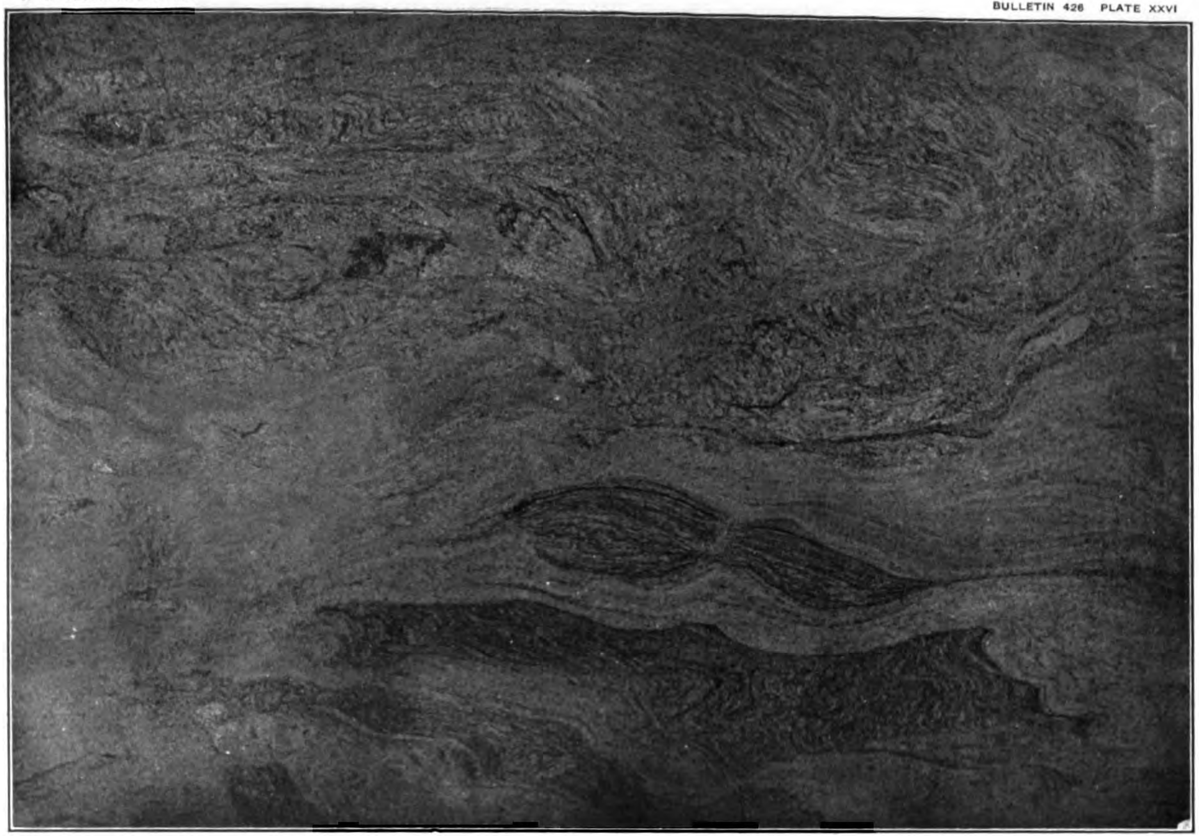
The following crushing tests were made on specimens of Lithonia contorted granite gneiss.

Crushing tests of granite gneiss from Lithonia, Ga.[a]

AT WASHINGTON NAVY-YARD, 1887.

Dimensions (inches).	Crushed at—	
	Pounds.	Pounds per square inch.
2.00 x 2.00 x 2.02	76,000	....
2.00 x 2.01 x 2.00	83,400	....
2.06 x 2.06 x 2.09	52,650	....
2.01 x 2.01 x 2.01	(b)	....
2.00 x 1.98 x 1.98	(b)	....
2.02 x 2.04 x 2.07	80,000	....
2.02 x 2.01 x 2.06	61,000	15,024
2.01 x 2.01 x 2.01	80,000	19,801
2.01 x 2.00 x 2.00	80,700	....
2.02 x 2.08 x 2.02	75,700	18,017
2.02 x 2.05 x 2.02	64,000	15,455

[a] Granite pavements, compiled by Venable Brothers, Atlanta, Ga., 1893.
[b] Did not crush at 85,000 pounds.



SURFACE OF GRANITE GNEISS, LITHONIA, DEKALB COUNTY, GA.

Crushing tests of granite gneiss from Lithonia, Ga.—Continued.

AT PURDUE UNIVERSITY, LAFAYETTE, IND.

Dimensions (inches).	Crushed at—	
	Pounds.	Pounds per square inch.
2.06 x 2.02 x 2.02	78,700	18,913
2.04 x 2.04 x 2.06	71,700	17,229
2.04 x 2.03 x 2.03	79,700	19,246
2.04 x 2.04 x 2.05	79,700	19,151
2.02 x 2.02 x 2.01	74,700	18,307
2.01 x 2.02 x 2.04	70,700	17,413

LITHONIA-CONYERS-LAWRENCEVILLE AREA.

GENERAL DESCRIPTION.

The Lithonia-Conyers-Lawrenceville area covers parts of five counties and lies immediately adjacent on its north and west sides to the famous Stone Mountain. (See map, fig. 19.) The area includes the extreme eastern part of Dekalb County and extends in a northeasterly direction through the northern and middle portions of Rockdale County, the western part of Walton County, and the southern half of Gwinnett County, into Jackson County, in the vicinity of Winder. The principal quarrying center is Lithonia, a station on the Georgia Railroad, in Dekalb County. Quarries have been worked in the vicinity of Conyers, Rockdale County, and a few scattered small openings have been operated near Snellville and Lawrenceville, Gwinnett County.

In the immediate vicinity of Lithonia and to the north and east the granite gneiss is exposed as flat-surfaced masses and in residual domelike bosses (Pl. XXVI), some of the latter rising several hundred feet above the surrounding plain. Pine (Little Stone), Arabia, Collinsville, and Rock Chapel mountains, in Dekalb County, and McDaniel Mountain, in Rockdale County, are the most conspicuous of the dome-shaped masses of granite gneiss in this area. Pine Mountain is the largest, and is second in size and importance as a producer of stone only to Stone Mountain, about 8 miles distant.

The readiness with which sheets of the stone of large size and of any desirable thickness can be raised over the slopes of the doming masses makes them important quarrying areas. The most extensive quarries in the Lithonia portion of the area are to be found on some of the domes of granite gneiss.

LITHOLOGIC CHARACTERS.

The rock is a hard, firm, close-textured, fine-grained biotite granite gneiss of medium-gray color. It is in the main highly contorted and usually thin banded, the black biotite and light-colored feldspars and quartz being more or less differentiated into layers. As compared with the bands of light-colored minerals those of biotite are very thin. In addition to forming distinct bands, the biotite is more sparingly distributed through the quartz-feldspar layers.

The principal minerals are orthoclase, microcline, plagioclase (oligoclase), quartz, biotite, a little muscovite, apatite, zircon, and magnetite. Some secondary chlorite, epidote, kaolin, and a light mica occur. Crystals of red garnet are very common in some of the quarries. The garnet forms in places thick lenses of considerable length, alternating with bands of the principal minerals, and is distributed through the rock as single crystals. Small bunches of black tourmaline, similar to those in the granite of Stone Mountain, in well-rounded areas of quartz and feldspar, are distributed through the gneiss, but are by no means so abundant as at Stone Mountain.

Orthoclase is the dominant feldspar and in part is intergrown with a plagioclase feldspar as microperthite. Microcline is subject to much variation, its general average being probably somewhat larger for the gneiss than for the even-grained granites. This increase in microcline in the gneiss can probably be accounted for as a result of pressure metamorphism, for numerous pieces of the mineral show some indications of a possible induced structure, such as might result from excessive strain. Plagioclase is likewise variable in amount, but, as indicated in the analyses on page 252, its general average is high, as shown by the N_2O being approximately equal to or greater molecularly than K_2O. Some muscovite is associated with the biotite. Rounded inclusions of quartz and feldspar are common to the larger feldspar individuals. Intergrowths of quartz with feldspar occur, but are less common than in the massive granites.

Pegmatite dikes in which black tourmaline is one of the minerals are present. Vertical joints are by no means conspicuously developed. They are widely spaced and their surfaces are in many places coated with damourite, which is slickensided, grooved, and striated, affording evidence of subsequent movement.

DESCRIPTIONS OF QUARRIES.

GENERAL STATEMENT.

Forty-six quarries have been worked in the Lithonia-Conyers-Lawrenceville granite gneiss area. These are distributed among five counties—Dekalb, Rockdale, Gwinnett, Jackson, and Walton. Dekalb County contains most of the quarries and all the larger ones; they are grouped about and near Lithonia, 20 miles east of Atlanta, as the quarrying center and shipping point on the Georgia Railroad.

All quarries within the area, both large and small, that are now operating or have been operated are listed below. Numerous small openings are not included in the list. Of the 46 quarries listed only a few were operating during the summer of 1908.

The description of the quarries will be limited to some of the larger and more important ones in each county. The stone from the numerous quarries over the area shows only slight if any variation in color, texture, and structure, so that description of each quarry would entail a useless amount of repetition. Moreover, the fresh rock from the several quarries, both large and small, seems equally well adapted to the uses made of it. Joints and pegmatite dikes are not so pronounced as in many granite areas, and in none of the quarries do they involve waste in operating.

Quarries in the Lithonia-Conyers-Lawrenceville granite gneiss area.

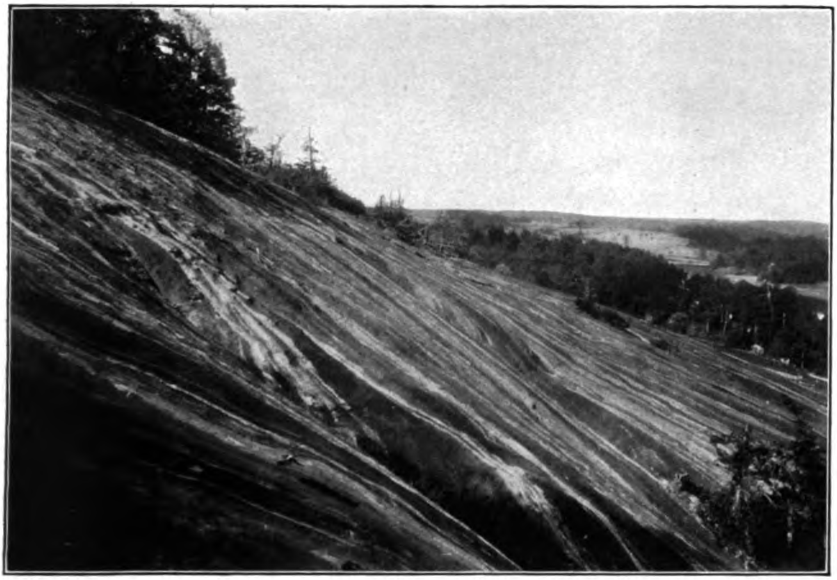
Quarry.	Location.	
	Post-office.	County.
Almond	Conyers	Rockdale.
Arabia Mountain	Lithonia	Dekalb.
Bosier	do	Do.
Brand	do	Do.
Braswell	do	Do.
Brantley	do	Do.
Bush	Winder	Gwinnett and Walton.
Cates	Grayson	Gwinnett.
Chupp, Jake	Lithonia	Dekalb.
Chupp, J. H	do	Do.
Chupp, J. L	do	Do.
Collinsville Mountain	do	Do.
Cooper	do	Do.
Crossley	do	Do.
Duncan	do	Do.
Ewing	Lawrenceville	Gwinnett.
Floyd	Redan	Dekalb.
Georgia Railroad	Lithonia	Do.
Goddard	do	Do.
Henderson	do	Do.
Jenkins	do	Do.
Johnson	do	Do.
Langley	Grayson	Gwinnett.
Lawrenceville	Lawrenceville	Do.
Lee Brothers	Lithonia	Dekalb.
McDaniel Mountain	do	Rockdale.
Pierce	Conyers	Do.
Pine (Little Stone) Mountain	Lithonia	Dekalb.
Powell	Conyers	Rockdale.
Reagin and Georgia Railroad	Lithonia	Dekalb.
Redwine & James	Conyers	Rockdale.
Rock Chapel Mountain	Lithonia	Dekalb.
Rockmore	Loganville	Walton.
Saunders	Winder	Jackson.
Sawyer	Snellville	Gwinnett.
Snell	do	Do.
Southern Granite Company	Lithonia	Dekalb.
Tilly	Conyers	Rockdale.
Tribble & Bennett	Grayson	Gwinnett.
Turner	Lawrenceville	Do.
Wade	Lithonia	Dekalb.
Walker	do	Do.
Weeks	do	Do.
Whitley	do	Do.
Whittaker	Conyers	Rockdale.
Wilson	Lithonia	Dekalb.

DEKALB COUNTY.

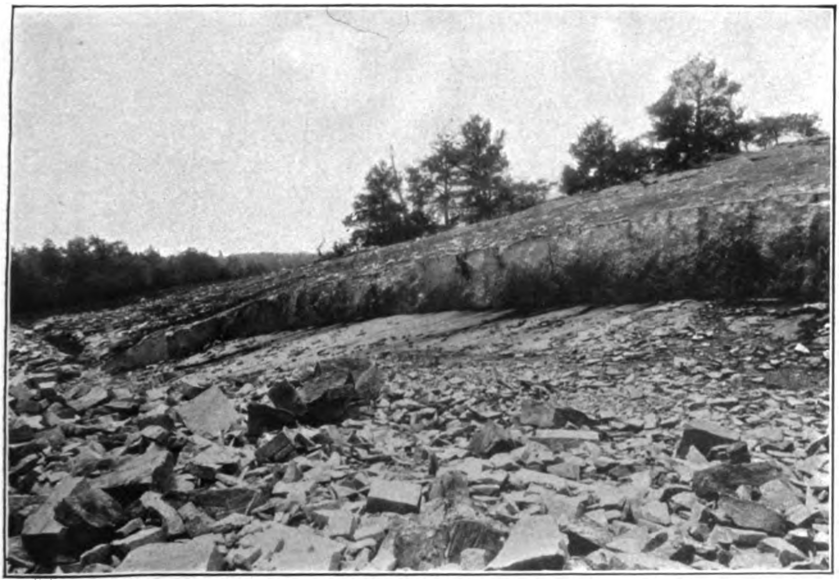
The *Arabia Mountain quarries* are opened on Arabia Mountain, which consists of two large dome-shaped granite gneiss masses, 3 miles south of Lithonia. The peaks are close together, having a northeast-southwest alignment and averaging about 85 feet high. The southwest peak is the higher and larger of the two. Quarries of large dimensions have been worked over the basal slopes and edges of the northeast peak, and less extensively on the east side. (See Pl. XXVII, *B*.) Development has not been so extensive on the southwest peak, but the stone has been "raised" over approximately half of its slope, preparatory to opening quarries. The south and southwest sides of the peak have not been touched. The rock is a contorted biotite granite gneiss of light-gray color, medium grain, and irregular banding. Garnet and magnetite are visible in the rock. Segregation veins of pegmatite and small dark areas of black tourmaline occur. The joint surfaces are mostly slickensided and are coated in some places with damourite, indicating movement in the rock mass. A chemical analysis of the rock from these quarries is given on page 252 (No. 5). The percentage of absorption for the rock is 0.050. A spur track is operated between the Georgia Railroad at Lithonia and the northeast peak.

The *J. L. Chupp quarries* comprise six large openings in a 10-acre flat-surfaced exposure about a mile from Lithonia. Work was first begun in 1882 and has been more or less continuous to the present time. An approximate estimate showed that about 50,000 feet of stone had been quarried annually for the ten years prior to 1900. The product was shipped to various cities in and outside of the State, and used principally for street purposes and to some extent in building. The rock is a contorted biotite granite gneiss of light-gray color and medium grain. It carries local thin bands of red garnet and is cut in places by thin pegmatite dikes.

The *Collinsville Mountain quarries* are about a mile east of south from Lithonia, on Collinsville Mountain, one of the smaller dome-shaped masses. The peak lies south of and adjacent to Little Pine Mountain. Its greatest elevation is less than 100 feet and its slopes are gentle, with partly rough and uneven surfaces. The main line of the Georgia Railroad passes directly over the south slope of the dome. Quarries have been worked over nearly the entire rock mass. The rock is a contorted biotite granite gneiss of light-gray color and irregular banding and is in places highly garnetiferous. Many of the garnets are of large size and are partly altered to brownish epidote. Crystals of magnetite and black tourmaline are distributed through the rock in the usual quantity. The product was shipped to different parts of the South for paving and general street work. During the summer of 1901 work was resumed on rather an extensive scale to supply orders from Washington, D. C., and St. Louis, Mo., for curbing. A crusher was operated on the property in order to work up the quarry waste.



A. EAST SLOPE OF PINE MOUNTAIN, A GRANITE GNEISS DOME, LITHONIA, DEKALB COUNTY, GA.



B. QUARRY FACE OF GRANITE GNEISS, ARABIA MOUNTAIN QUARRIES, NEAR LITHONIA, DEKALB COUNTY, GA.

rock as single grains and crystals. Some magnetite and black tourmaline crystals are disseminated through the rock. The product was worked into blocks, curbing, and flagging, and used for street purposes.

The *Pine Mountain quarries*, on Pine Mountain (Little Stone Mountain) 1 mile east of Lithonia, are the most extensive quarries in the granite gneiss area. Pine Mountain is the largest of the doming masses of granite gneiss in the area and is second in size only to Stone Mountain. Its height is about 150 feet. Its slopes are rounded and have easy gradients and for the most part are bare of plant growth. The worked quarries are limited to the north and southwest slopes of the mountain, which have been "raised" and worked from the base nearly to the top. The southwest slope has been worked to a greater depth than the north slope. (See Pl. XXVII, *A*.)

The rock is the typical contorted biotite granite gneiss, of light-gray color, medium grain, and irregular banding. Scattered folia of muscovite are visible in the hand specimens. Here and there small segregation veins of pegmatite and dark areas of biotite occur. Scattered grains of magnetite and garnet and rarely areas of tourmaline have been noted in places. The general absence of visible jointing in this mass is a very noticeable feature.

The chemical composition of the rock is shown in an analysis on page 252, and the results of strength tests on 2-inch cubes are given on page 252. A test to determine the capacity of the rock to absorb water, made by F. W. Clarke, showed a gain in weight of 0.2 gram (from 381.5 to 381.7 grams) after soaking for forty-eight hours.

The Pine Mountain quarries were the first to be opened and worked in the Lithonia area. They are among the largest and most productive in the area, the product being shipped to many of the principal towns and cities in the South and West. The ease with which the stone can be quarried is of considerable economic importance. Beginning at the bottom of the slope, one raise, ranging from 7 to 11 feet in thickness, is readily effected, extending nearly or quite to the top. This method of quarrying the stone is equally available for each of the doming masses in the area. It is very similar to that in use in the Mount Airy quarries in North Carolina, described on pages 150–151.

The shipments from these quarries have amounted to as much as 30 carloads of stone a day in some years. The product is extensively used in the form of blocks and curbing for street work.

The *Southern Granite Company's quarry*, three-quarters of a mile north of Lithonia, includes about 5 acres of a flat-surfaced exposure worked to a depth of 20 feet. The product, worked into blocks and curbing, is shipped to the principal towns in the South. The rock is a contorted biotite granite gneiss of good grade. A considerable sprinkling of magnetite grains and several small areas of molybdenite occur. The following analyses of the fresh and partly decayed rock were made by the writer:

Analyses of granite from Southern Granite Company's quarry, near Lithonia, Ga.

	Fresh.	Partly decayed.
Silica (SiO_2)	72.96	74.53
Alumina (Al_2O_3)	14.70	13.70
Iron oxide (Fe_2O_3)	1.28	1.15
Magnesia (MgO)	.07	Trace.
Lime (CaO)	1.28	.95
Soda (Na_2O)	4.18	4.41
Potash (K_2O)	4.73	5.20
Ignition	.23	.81

The *Rock Chapel Mountain quarries* are opened on the doming mass known as Rock Chapel Mountain, 3 miles northeast of Lithonia. This is one of the smaller domes in the Lithonia area. Fourteen quarries have been raised over the peak, but no stone has been removed except from the west-side quarry. The raised quarries extend from the top down to the base of the north and northwest sides. The rock is a contorted biotite granite gneiss of light-gray color and medium grain. The sap (partly decayed rock) is very thin and consists of the usual hard, firm, reddish material.

The *Wilson quarry*, 2½ miles northeast of Lithonia, consists of five large openings close together in flat-surfaced outcrops. Systematic quarrying was first begun in 1891. In 1898, between January and August, 150 carloads of the stone were shipped. The rock is the contorted biotite granite gneiss, containing a goodly sprinkle of large magnetite grains. The partly decayed rock (sap) is very thin and usually of a reddish color, due to the iron stain derived from the partial decay of the biotite.

The *Whitley quarry*, a quarter mile southwest of the Wilson quarry, includes six openings almost joining one another. The product is used for paving and curbing in street work. The rock is a contorted biotite granite gneiss of excellent grade, containing the usual sprinkle of magnetite grains. There are a few thin veins of pegmatite in it.

GWINNETT COUNTY.

The *Bush quarry*, a quarter of a mile south of Winder, includes a number of openings in flat-surfaced exposures of the rock. The Gwinnett-Walton county line divides the property, placing the openings partly in one county and partly in the other. The rock is a contorted biotite granite gneiss of variable color and texture, cut by many pegmatite dikes. It is not so highly contorted as the gneiss in the vicinity of Lithonia, described above. When broken across the schistosity the fractured surface presents roughly an augen-gneiss appearance, the quartz-feldspar grains being partly lens-shaped and irregularly wrapped by the layers of biotite.

The *Lawrenceville quarry* lies near the limits of the town of Lawrenceville, 460 yards from the Seaboard Air Line Railway. The opening is made in a 3-acre flat-surfaced exposure of the rock and has been worked to a depth of 10 feet. The rock is a contorted biotite granite gneiss of light-gray color and medium grain. Its minerals are orthoclase, microcline, plagioclase, quartz, and biotite, with accessory zircon and secondary chlorite, epidote, and a light-colored mica. The larger feldspar and quartz individuals inclose smaller grains of the two minerals, of irregular outline.

The *Snell quarry* includes four large openings in a flat-doming mass 2 miles south of Snellville. Quarrying was begun here in 1883. The rock is a contorted biotite granite gneiss of light-gray color and medium grain, cut by numerous pegmatite dikes several inches thick. The minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, biotite, and a little muscovite, with secondary chlorite, garnet, epidote, and a light-colored mica. Microcline and orthoclase are about equal in amount. The large feldspar individuals contain rounded grains of quartz and feldspar. A chemical analysis of this rock (No. 3) and an absorption test are given on page 252.

The *Turner quarry* comprises three large openings in a 6-acre exposure of gneiss 5 miles southeast of Lawrenceville. The product has been used principally in railroad construction. The rock is a biotite granite gneiss of light-gray color and medium grain. The bands are less contorted than in the rock near Lithonia. There are very few pegmatite dikes. The principal minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, and biotite. Slender foils of muscovite are developed along the roughly parallel lines of fracture.

JACKSON COUNTY.

For several miles on the north and west sides of Winder, in the southeastern part of Jackson County, the Lithonia belt of contorted biotite granite gneiss outcrops as flat-surfaced masses. So far as the writer has been able to trace it, the Jackson County outcrops mark the northernmost extension of the Lithonia-Conyers-Lawrenceville granite gneiss area. Several openings have been made just beyond the north and west limits of the town of Winder, and some of the stone has been quarried for local purposes.

The rock exposed in the openings is fairly uniform and somewhat highly contorted and is composed of an admixture of feldspar, quartz, and biotite. It can hardly be distinguished in the hand specimens from the similar rock quarried at Lithonia, although on close inspection slight differences are discernible between the rocks of the two localities. The Jackson County rock contains an increased amount of biotite in larger flecks and perhaps a little less quartz and more feldspar than that at Lithonia. It is also somewhat coarser in grain and as a rule less highly contorted than the typical granite gneiss at Lithonia. The variations are regarded as very slight indeed, for the extreme portions of so extensive a granite area.

ROCKDALE COUNTY.

The *McDaniel Mountain quarries* are opened on McDaniel Mountain, a doming mass of granite gneiss located near the DeKalb County line, about three-fourths of a mile east of the north peak of Arabia Mountain. Its height will not exceed 100 feet and its slopes are gentle. The quarries are confined to the west and southwest slopes of the peak. On the south and northwest slopes surface raises have been made but the stone has not been worked up. The rock is a contorted biotite granite gneiss of light-gray color, medium grain, and irregular banding. It is cut in places by a few veins of pegmatite and locally contains a sprinkle of magnetite grains.

The *Pierce quarry*, on Yellow River, 3 miles north of Conyers, is a large one and much stone has been taken from it, but it has been idle for more than twelve years. The rock is a contorted biotite granite gneiss of light-gray color and medium grain, containing many magnetite grains distributed through it. The principal minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, and biotite, with some secondary chlorite and epidote.

The *Powell quarry* comprises four openings in a 4-acre exposure about 2 miles east of Conyers. It was last worked in 1896. The rock is a highly contorted biotite granite gneiss of the usual color and texture, containing numerous garnets in places. The principal minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, biotite, and a little muscovite, with secondary chlorite, epidote, and a light-colored mica. Roughly rounded grains of quartz and feldspar are common as inclosures in the larger individuals of these two minerals. Intergrowths of the quartz and feldspar occur.

The *Tilly quarry* includes three large openings close together in a 5-acre flat-surfaced exposure of the rock, 2 miles northwest of Conyers. The rock is of the same grade of contorted biotite granite gneiss as that of the Powell quarry, described above, and consists of the same minerals in the same order of abundance. A chemical analysis of this rock is given on page 252 (No. 4).

The *Turner quarry*, in a 6-acre exposure near Conyers, about a mile from the Georgia Railroad, was opened in 1890. A large quantity of the stone has been quarried and used principally for Belgian blocks. The rock is a highly contorted biotite granite gneiss of light-gray color, containing considerable magnetite grains in places. Some bands of garnet occur and the rock is cut by a few thin veins of pegmatite. The principal minerals are the same as for the similar rock described above.

WALTON COUNTY.

The Lithonia-Conyers-Lawrenceville granite gneiss area includes a portion of eastern Walton County. Less than half a dozen small openings, from which granite gneiss has been quarried, have been made in the county, most of them near the village of Loganville. No stone has been shipped. Some variation in the color and texture of the rock is observed, although many of the hand specimens can not be distinguished from those of the typical granite gneiss of the Lithonia area.

ODESSA-MOUNTVILLE AREA.

INTRODUCTORY STATEMENT.

The Odessa-Mountville area extends in a general east-west direction through parts of Troup and Meriwether counties, in middle southwestern Georgia, near the Alabama line. Hand specimens of the rock from this area are indistinguishable from those of the Lithonia-Conyers-Lawrenceville area, and the two rocks are identical in mineral and chemical composition. The results of physical tests and chemical analysis of specimens of the Odessa rock are given on page 252. The granite gneiss is exposed along the streams and on the interstream areas as flat-surfaced masses, some of which are of considerable extent. Only a few quarries are opened in the area.

LITHOLOGIC CHARACTERS.

The gneiss is an irregularly banded, highly contorted biotite granite gneiss of medium light-gray color and fine to medium grain. Its minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, and biotite, with accessory magnetite, zircon, and apatite. Secondary chlorite and epidote occur. The potash feldspar is intergrown with a second feldspar in microperthitic fashion. Microcline and plagioclase usually average high in quantity but are rather variable. The larger feldspar and quartz individuals contain rounded inclosures of the same minerals. Magnetite crystals, mostly visible to the naked eye, are disseminated through the gneiss of this area, as through that of the Lithonia-Conyers-Lawrenceville area.

The granite gneiss is intersected in places by dikes of pegmatite and of biotite granite of dark-gray color and fine grain. Dark segregated areas (knots) of black mica (biotite) occur to a minor extent.

DESCRIPTIONS OF QUARRIES.

Although large outcrops of biotite granite gneiss are numerous over the Odessa-Mountville area, very few quarries have been opened. The two principal ones are the Odessa quarry, in Meriwether County, and the Mountville quarry, in Troup County.

The *Odessa quarry*, 6 miles west of Greenville and half a mile north of Odessadale, in Meriwether County, lies in a 15-acre exposure of the rock and comprises about 2 acres worked to a depth of 10 feet. It was worked for a period of three years after being first opened about fourteen years ago, the product being used principally for river work by the United States Government on St. Johns River in Florida.

The rock is a highly contorted biotite granite gneiss of light-gray color, medium grain, and irregular banding. It is entirely similar to the granite gneiss quarried near Lithonia, Dekalb County, and hand specimens of the rock from the two localities can not be distinguished. Its principal minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, and biotite. Rounded inclusions of quartz and feldspar are contained in the larger feldspar individuals. The biotite is partly altered to chlorite. Pressure effects are indicated in peripheral shattering, wavy extinction, and lines of fracture in the larger grains of quartz and feldspar. Dikes of pegmatite and of biotite granite of dark-gray color and fine grain cut the granite gneiss and in places the rock contains segregated areas (knots) of black mica (biotite) and scattered grains of magnetite.

A chemical analysis of this rock is given on page 252 (No. 1); the results of physical tests are given on page 252.

The *Mountville quarry*, 8 miles east of Lagrange and 1 mile west of Mountville, is opened in a 4-acre flat-surfaced outcrop. The small quantity of stone quarried here has been used for street purposes.

The rock is a highly contorted biotite granite gneiss of light-gray color, medium grain, and irregular banding, carrying a few scattered grains of magnetite in places. Its minerals are orthoclase, microcline, plagioclase (oligoclase), quartz, and biotite, with accessory zircon, apatite, and magnetite. The secondary minerals are chlorite and epidote. Orthoclase is intergrown with a second feldspar and is largely microperthitic. Inclosures of quartz and feldspar are contained in the larger feldspar grains. The thin sections exhibit evidences of pressure effects similar to those in the Odessa quarry described above. A comparative study of the thin sections of the rock with those of the granite gneiss from Lithonia reveals their practical identity.

MERIWETHER COUNTY.

The Flat Shoals area of foliated granite is 12 miles east of Greenville and about the same distance west of Zebulon. Extensive exposures of the rock can be traced along Flint River for some distance in Meriwether and Pike counties. The outcrops extend back from the river for some distance on the Meriwether County side. The area is somewhat remote from the railroad, and except for a small opening made some years ago at Freeman's mill it is wholly undeveloped.

The rock is a foliated biotite granite of light-gray color and medium grain. Its minerals are microperthitic orthoclase, microcline, plagioclase (albite), quartz, and biotite, with accessory apatite and zircon. The secondary minerals are chlorite, epidote, and a light-colored mica. Finely crushed grains of the quartz and feldspar are abundant about the borders of the larger individuals of the two minerals. The following chemical analysis was made by the writer:

Analysis of foliated granite from Flat Shoals, Meriwether County, Ga.

Silica (SiO_2)	74.80
Alumina (Al_2O_3)	15.46
Iron oxide (Fe_2O_3)	1.04
Magnesia (MgO)	.11
Lime (CaO)	.82
Soda (Na_2O)	4.80
Potash (K_2O)	2.52
Ignition	.31

COWETA COUNTY.

About 11 miles northwest of Newnan, the county seat of Coweta County, are large areas of foliated granite (granite gneiss) bordering Chattahoochee River and extending across the river into Carroll and Heard counties on the north and west, respectively. The rock outcrops as flat-surfaced and low dome-shaped masses, forming the prominent hills and ridges in the area. The topography is less subdued here than in other portions of the county. The most extensive outcrop of the gneiss is that known as Flat Rock, which derives its name from the character of the exposure at the surface. No quarries have been opened in it. The main body of the rock in Coweta County is 6 miles from Sargent, the nearest railroad station.

The rock is a thinly banded biotite granite gneiss of light-gray color and medium grain. Its minerals are microperthitic orthoclase and microcline in nearly equal amounts, plagioclase, quartz, biotite, and muscovite, with accessory zircon and apatite and secondary epidote, garnet, chlorite, and light-colored mica. Pressure effects are manifested in the peripheral shattering of the larger quartz and feldspar individuals. Inclusions are common to the quartz, feldspar, and biotite. Pegmatite dikes an inch or more in thickness cut the rock in places. A comparison of the following chemical analysis, made by the writer, with that of the Flat Shoals rock, in Meriwether County (p. 264), and that of Flat Rock, in Heard County (p. 265), establishes their practical chemical identity.

Analysis of granite gneiss from Flat Rock, Coweta County, Ga.

Silica (SiO_2)	73.95
Alumina (Al_2O_3)	14.23
Iron oxide (Fe_2O_3)	1.29
Magnesia (MgO)	.23
Lime (CaO)	1.07
Soda (Na_2O)	4.61
Potash (K_2O)	5.29
Ignition	.25

HEARD COUNTY.

An extensive body of foliated granite occurs 3 miles southwest of Franklin, the county seat of Heard County. There are at least 400 acres of the rock exposed in one continuous flat-surfaced outcrop, broken here and there by knolls of slight elevation. Parts of the exposure are timbered. Small amounts of the stone have been quarried from time to time during the last fifty years for strictly local use. Seven openings have been made in all.

The rock is a thinly foliated biotite granite, of light-gray color and fine grain. Biotite is distributed along roughly parallel lines through the rock in flattened areas of grouped shreds, which vary from 2 to 20 millimeters in diameter. When the rock is broken at angles to the foliation the parallel arrangement of the mica (biotite) is very noticeable. The rock is composed of orthoclase, microcline, and plagioclase (oligoclase) in about equal amounts, quartz, biotite, and scattered intergrown shreds of muscovite. Here and there grains of reddish garnet occur. The biotite is partly altered to chlorite. Rounded areas of quartz are inclosed in the larger feldspar grains. The orthoclase is partly intergrown with a second feldspar as microperthite. Partial peripheral shattering of the quartz and feldspar is shown in the thin sections.

The following chemical analysis of the rock, made by the writer in the Georgia Survey laboratory, will show its composition:

Analysis of foliated granite from Flat Rock, Heard County, Ga.

Silica (SiO_2)	74.96
Alumina (Al_2O_3)	13.71
Iron oxide (Fe_2O_3)	.90
Magnesia (MgO)	.24
Lime (CaO)	1.02
Soda (Na_2O)	4.68
Potash (K_2O)	4.79
Ignition	.44

The specific gravity is 2.648.

NEWTON COUNTY.

Newton County contains a number of areas of irregularly banded biotite gneiss of coarse grain and medium to dark gray color. Among these are two rather large flat-surfaced exposures, which may be of commercial importance—one 2 miles northwest and the other 1½ miles southeast of Covington, the county seat. Considerable stone has been quarried from the mass exposed 2 miles northwest of Covington.

The rock is a biotite granite gneiss of dark-gray color and coarse grain, and is very irregularly banded. When compared with the granite gneiss of the Lithonia area in Dekalb County, it shows a striking contrast in color and texture. In addition to its coarser grain and darker color, it lacks the hardness, compactness, and lively appearance of grain so characteristic of the Lithonia rock. Thin sections of the gneiss show the principal minerals to be microcline, orthoclase, plagioclase, quartz, and biotite, and the secondary minerals chlorite, kaolin, and a light-colored mica. Intergrowths of the feldspar with quartz are somewhat common. The larger grains of microcline contain rounded inclosures of both quartz and feldspar.

A chemical analysis of the gneiss, made by the writer, shows the following composition:

Analysis of gneiss from Newton County, Ga.

Silica (SiO_2)	71.20
Alumina (Al_2O_3)	15.46
Iron oxide (Fe_2O_3)	1.17
Magnesia (MgO)	.33
Lime (CaO)	1.36
Soda (Na_2O)	4.96
Potash (K_2O)	5.30
Ignition	.52

CLARKE COUNTY.

An irregularly banded gneiss of dark-gray color and coarse grain is extensively exposed along Oconee River within and beyond the limits of Athens, and considerable of the stone has been quarried and used in that city.

The rock is a biotite gneiss of dark-gray color and coarse grain. It is of porphyritic texture in places, the feldspar phenocrysts measuring from 30 to 40 millimeters in length. Thin sections of the gneiss show the principal minerals to be orthoclase, microcline, plagioclase, quartz, and biotite, with some muscovite. The biotite is partly altered to chlorite and the feldspars to kaolin and a light-colored mica. The plagioclase is more altered than the potash feldspars. Intergrowths of quartz with feldspar are noted here and there.

A chemical analysis of the gneiss, made by the writer, is given below:

Analysis of gneiss from Clarke County, Ga.

Silica (SiO_2)	69.51
Alumina (Al_2O_3)	16.32
Iron oxide (Fe_2O_3)	2.38
Magnesia (MgO)	1.28
Lime (CaO)	1.84
Soda (Na_2O)	3.82
Potash (K_2O)	3.47
Ignition	1.11

CHAPTER VIII.

THE GRANITES OF ALABAMA.

THE CRYSTALLINE AREA.

The crystalline area in Alabama, representing the extreme southwestern extension of the Piedmont Plateau in the southeastern Atlantic States, is roughly triangular in shape and has an estimated area of less than 5,000 square miles. Its greatest dimension is along the Georgia-Alabama boundary, where it extends from Columbus, Ga., northward for an approximate distance of 100 miles. From this boundary it narrows toward the west, and near the central portion of Alabama it passes beneath and is concealed by the cover of younger sediments. On the south and southwest the rocks of the crystalline area pass beneath the coastal plain sediments and on the northwest they are covered by the Paleozoic sediments.

The crystalline area occupies the eastern north-central portion of the State, and comprises the whole or a part of Chambers, Chilton, Clay, Cleburne, Coosa, Elmore, Lee, Macon, Randolph, Talladega, and Tallapoosa counties. Both granites and gneisses occur within this area, and not, so far as known, elsewhere in the State, but no quarrying industry has been established and these rocks are commercially almost wholly undeveloped.

According to the geologic map of the State and the accompanying chart, published by the State survey in 1894, the rocks of the area are grouped into those "fully crystalline" (Archean) and those "imperfectly crystalline," which are of uncertain age, but are referred partly to the Algonkian and partly to the Cambrian or later. Of the "fully crystalline" rocks, mica-schist is the prevailing type, with some gneiss and granite. Hornblendic, pyroxenic, and chrysolitic rocks are reported. The "imperfectly crystalline" rocks comprise an unknown thickness of quartzites, conglomerates, and clayey and sandy shales.

THE GRANITES.

Granite in considerable quantity and of good quality occurs in a few localities in the crystalline area of Alabama, but no regular quarries have been opened. It is reported in a position favorable for quarrying at different points in Lee, Tallapoosa, Chambers, Randolph, Elmore, Chilton, Coosa, Cleburne, and Clay counties.

The granite outcrops in low domelike masses of naked rock, some of them 200 acres or more in extent, locally called "flat rocks." According to Smith and McCalley,[a] the largest of these flat-rock areas lie near Almond, Blakes Ferry, Rock Mills, and Wedowee, in Randolph County; near Milltown, in Chambers County; and southwest of Roxana and along Sougahatchee Creek, in Lee County. Smaller exposures of granite are reported from each of the other counties in the crystalline area.

Gneisses are associated with the massive granites and in places both rocks yield desirable stone for building and other purposes. The factories, dams, and bridge piers at Tallassee and vicinity were constructed of the gneissoid granite, which is exposed along Tallapoosa River in this locality. Smith and McCalley[b] say that some granite has been quarried and used locally about Wedowee, in Randolph County, and at Rockford and other places in Coosa County. Rough stone was quarried in many of the counties in the crystalline area traversed by the Central of Georgia Railroad, and used in the construction of the culverts and bridge foundations along the road.

The small amount of granite and gneiss thus far quarried in Alabama has been consumed entirely by the local trade, which has been very slight. Should a demand arise for this kind of stone favorable quarry sites could be obtained and the stone developed. The most promising areas of granite in Alabama are remote from lines of transportation, a fact which, taken in connection with the meager demand for granite, which is readily supplied from Georgia, is unfavorable to development of the areas.

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[a] Smith, E. A., and McCalley, Henry, Index to the Mineral Resources of Alabama: Alabama Geol. Survey, 1904, p. 67.

[b] Idem, p. 67.

APPENDIX.

STATISTICS OF PRODUCTION.

The following tables show the production of granite in the area covered by this report, by States and uses, for the years 1905, 1906, 1907, and 1908:[a]

Production of granite in southeastern Atlantic States, 1905–1908.

1905.

State.	Building stone.		Monumental stone.		Paving blocks.		Curbing.	Flagging.
	Rough.	Dressed.	Rough.	Dressed.	Number.	Value.		
Georgia	$89,350	$101,375	$50,038	$25	7,946,000	$296,750	$246,543	$2,310
Maryland	233,716	125,177	38,860	4,600	869,000	38,900	21,742	7,419
North Carolina	75,125	228,726	5,969	3,142	1,139,675	48,234	70,535	3,773
South Carolina	18,989	40,670	29,740	14,250	348,500	9,604	14,197	1,178
Virginia	31,224	28,950	10,415	37,180	913,440	19,220	8,948	2,550
	448,404	524,898	135,022	59,197	11,216,615	412,708	361,965	17,230

State.	Crushed stone.			Rubble.	Riprap.	Other.	Total.
	Road making.	Railway ballast.	Concrete.				
Georgia	$7,300	$77,717	$62,723	$29,314	....	$7,722	$971,207
Maryland	133,599	8,046	212,592	102,733	$2,996	26,668	957,048
North Carolina	27,736	56,574	34,161	6,311	2,842	1,450	564,578
South Carolina	900	28,876	70,392	10,630	1,901	55,957	297,284
Virginia	21,175	69,360	166,364	28,961	27,236	807	452,390
	190,710	240,573	546,232	177,949	34,975	92,604	3,242,507

1906.

State.	Building stone.		Monumental stone.		Paving blocks.		Curbing.	Flagging.
	Rough.	Dressed.	Rough.	Dressed.	Number.	Value.		
Georgia	$109,215	$26,350	$56,010	....	3,927,500	$123,211	$189,524	$750
Maryland	211,524	113,693	80,780	$1,730	1,126,082	51,539	27,745	3,788
North Carolina	62,059	289,705	17,477	5,733	974,330	33,428	124,499	3,762
South Carolina	26,910	8,564	35,690	....	348,615	11,340	45,605	10,700
Virginia	18,158	....	15,804	16,936	1,385,000	29,536	14,339	1,216
	427,866	438,312	205,761	24,399	7,761,527	249,154	401,712	20,216

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[a] Mineral Resources U. S. for 1905 to 1908, U. S. Geol. Survey.

Production of granite in southeastern Atlantic States, 1905–1908—Continued.

1906.

State.	Crushed stone.			Rubble.	Riprap.	Other.	Total.
	Road making.	Railway ballast.	Concrete.				
Georgia	$19,400	$150,690	$81,400	$27,515	$7,000	$1,250	$792,315
Maryland	125,655	5,803	171,869	52,563	4,290	32,902	883,881
North Carolina	18,691	134,800	60,762	5,688	4,140	18,103	778,847
South Carolina	6,825	11,796	56,896	6,665	750	26,257	247,998
Virginia	34,981	64,386	85,077	28,477	31,790	200	340,900
	205,552	367,475	456,004	120,908	47,970	78,712	3,043,941

1907.

State.	Building stone.		Monumental stone.		Paving blocks.		Curbing.	Flagging.
	Rough.	Dressed.	Rough.	Dressed.	Number.	Value.		
Georgia	$89,675	$76,252	$31,100	$1,000	5,410,000	$151,181	$215,758	$5,515
Maryland	107,694	55,781	13,657	8,928	901,225	56,585	23,279	13,406
North Carolina	50,062	319,821	16,010	41,120	1,115,859	65,379	63,061	4,236
South Carolina	9,425	900	50,515	....	239,086	5,253	18,491	25
Virginia	19,350	13,275	8,039	9,787	685,100	18,072	6,000	....
	276,206	466,029	119,321	60,835	8,351,270	296,470	326,589	23,182

State.	Crushed stone.			Rubble.	Riprap.	Other.	Total.
	Road making.	Railway ballast.	Concrete.				
Georgia	$25,000	$152,297	$60,896	$26,954	$925	$22,050	$858,603
Maryland	282,310	41,266	490,378	77,901	7,266	5,302	1,183,753
North Carolina	53,939	175,847	106,497	6,823	2,941	740	906,476
South Carolina	25,887	17	4,500	13,939	25	400	129,377
Virginia	59,937	50,804	167,960	16,350	28,852	....	398,426
	447,073	420,231	830,231	141,967	40,009	28,492	3,476,635

1908.

State.	Building stone.		Monumental stone.		Paving blocks.		Curbing.	Flagging.
	Rough.	Dressed.	Rough.	Dressed.	Number.	Value.		
Georgia	$60,850	$125,350	$27,450	$9,500	4,735,770	$135,510	$346,383	$36,000
Maryland	119,094	48,407	6,824	3,273	692,538	71,316	26,003	3,869
North Carolina	109,919	144,261	29,822	46,834	3,679,745	122,488	99,070	8,258
South Carolina	12,699	12,012	52,565	18,697	351,250	12,277	11,670	100
Virginia	26,769	11,500	12,664	22,303	358,664	10,173	6,130	....
	329,331	341,530	129,325	100,607	9,817,967	351,764	489,256	48,227

State.	Crushed stone.			Rubble.	Riprap.	Other.	Total.
	Road making.	Railway ballast.	Concrete.				
Georgia	$2,500	$9,543	$50,518	$119,516	$36,000	$11,712	$970,832
Maryland	206,505	32,923	143,838	60,359	7,751	32,280	762,442
North Carolina	114,474	33,612	27,333	4,933	730	22,538	764,272
South Carolina	30,300	27,500	35,000	9,475	73,984	1,595	297,874
Virginia	21,670	71,704	102,936	18,270	16,336	1,075	321,530
	375,449	175,282	359,625	212,553	134,801	69,200	3,116,950

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UNITED STATES GEOLOGICAL SURVEY
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MANGANESE DEPOSITS OF THE UNITED STATES

WITH SECTIONS ON

FOREIGN DEPOSITS, CHEMISTRY, AND USES

BY

EDMUND CECIL HARDER

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MANGANESE DEPOSITS OF THE UNITED STATES.

By Edmund Cecil Harder.

INTRODUCTION.

This report is the result of an attempt to present as briefly as possible all available important information concerning manganese, including accounts of the deposits, the geology and chemistry of the ores, the methods of mining, and the uses of the metal and the nature and extent of the industries to which it gives origin. It is not designed to be an exhaustive study of manganese, but is chiefly a brief account of its principal sources of supply, both domestic and foreign, and of its useful applications. With regard to the foreign sources, most emphasis is laid on those districts that supply the United States with ore.

Manganese is obtained commercially from manganese ores, manganiferous iron and silver ores, and manganiferous residuum from zinc roasting.

Manganese ores are found in many parts of the United States, but at only a few places do they occur in sufficient quantity to be of high commercial value. They have been mined in the New England, Appalachian, and Piedmont regions in the eastern United States, in northern Arkansas, and, to a small extent, in central-western California. The principal producing mines have been those in the Blue Ridge region and the James River–Staunton River region of Virginia, the Cartersville and Cave Spring districts of Georgia, the Batesville district of Arkansas, and the Livermore-Tesla district of California. (See Pl. I, in pocket.)

Manganiferous iron and silver ores are also widely distributed. The former have been mined for their manganese content in the New England, Appalachian, and Piedmont regions in the eastern United States, in northern Arkansas, and in a few localities in the Lake Superior district, and the latter in several western silver districts, principally Leadville. In many manganiferous-ore deposits, however, the manganese content is so low that the ores are used only for the other metals which they contain. Such is the case with most of the manganiferous ores of the Lake Superior district, of the Appalachian region, and of the western silver districts.

Manganiferous zinc residuum is obtained only from zinc oxide works using New Jersey manganiferous zinc ores.

The manganese ores proper and the manganiferous ores are so closely associated that even in detail it is hard to separate them. In this report, therefore, they are discussed together under the same general headings.

The manganese and manganiferous ore deposits throughout the United States are largely secondary concentration deposits. Such are the ores of eastern United States, except certain rhodonite deposits, and such also are the ores in northern Arkansas, in the Lake Superior region, at Leadville and in other silver districts, and in western California. A few deposits of bog manganese ore occur locally, and these also are secondary concentrations. The rhodonite and rhodochrosite in the unoxidized portions of the silver veins at Butte, however, are primary concentrations, as are also the manganese silicate veins in central Texas and elsewhere.

The secondary manganese deposits of the eastern United States have originated directly or indirectly by the concentration of manganese once contained in manganese-bearing silicates of the crystalline rocks of this region. The deposits of the Piedmont region and some of the New England deposits are direct accumulations of manganese from this source, and the manganese of the Appalachian deposits has been derived from this original source through sedimentation, these ores having accumulated from manganese disseminated through sedimentary rocks, the materials of which were obtained from crystalline areas.

The northern Arkansas ores are largely reconcentrations from low-grade secondary deposits derived by sedimentation from old crystalline rocks, while the California ores are concentrations within chert lenses of material originally present in a disseminated form. The western manganiferous silver ores are the result of oxidation and concentration of primary deposits derived from igneous intrusion.

Bog manganese deposits have accumulated largely from deposition of manganese by waters issuing from springs. The bog deposits of New England, New York, Wisconsin, and those near Wickes, Mont., have been obtained directly from manganese-bearing silicates in igneous or metamorphic rocks; others, as those in central Arkansas and at Golconda, Nev., have been derived from waters issuing from sedimentary formations.

Manganese mining has never been a very important industry in the United States, owing to the small extent and the discontinuous and scattered nature of most of the deposits. Nearly all the ore mined must be either washed or sorted or both. Single pockets are of small extent and are soon exhausted, discouraging the erection of expensive concentrating plants.

In the eastern United States the ore is mined either by open cuts or by underground workings, according as the deposit is near the surface or some distance underground. Cars are used for carrying the ore from the mines when the open cuts or underground workings are of considerable extent; buckets and wheelbarrows when the workings are small. The ore is washed either by hand or in log washers. In the larger workings, as at Crimora, Va., several sets of log washers are employed. After washing, the ore is screened to separate the large fragments from the small ones. Frequently the fragments have to be sorted by hand to separate manganiferous iron ores from pure manganese ores, or to separate high-grade ores from highly siliceous ores containing sand grains and sandstone or chert fragments.

The crude mining methods that naturally result from the conditions stated make the concentration of ores slow and expensive, so that the resulting product can not compete on the market with foreign high-grade ores which do not require concentration.

Most of the manganese ore consumed in this country is imported from Brazil, India, and Cuba, smaller amounts being obtained from Russia, Germany, Great Britain, Belgium, Japan, the East Indies, and other countries. The total quantity of manganese ore imported from the beginning of 1900 to the end of 1908 was 1,777,653 long tons; the domestic production of manganese ore during the same period was 60,001 tons. Besides the raw ore there are considerable quantities of ferromanganese and spiegeleisen imported annually.

The imported raw ore is used largely in the manufacture of iron-manganese alloys, and these, together with the imported alloys, are consumed in steel manufacture. A considerable quantity of high-grade foreign ore is used in the manufacture of dry cells for electric batteries. Most of the domestic manganese ore, with perhaps a small portion of the imported ore, is used in the manufacture of brick and pottery as a coloring material, or for other chemical purposes. Only a small portion of the domestic ore is used in steel manufacture. Manganiferous ores of iron and silver are used both in the manufacture of iron-manganese alloys and as flux in smelting copper, lead, and silver ores. The manganiferous residuum from zinc-oxide works using New Jersey manganiferous zinc ores has been used in the manufacture of spiegeleisen for the last forty years.

The material of this report is in part the result of personal investigation by the writer and in part a compilation of facts from all available sources. In a trip occupying most of the months of January, February, March, and April, 1908, the writer covered all of the important manganese districts of the United States and many unimportant ones. The part of the report describing the deposits of these districts is therefore based on original observations. The chapters on foreign manganese deposits and on the chemistry and uses of manganese have been compiled from innumerable sources.

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CHAPTER I.

SOURCES OF MANGANESE.

The commercial sources of manganese are four, namely, (1) manganese ores, (2) manganiferous iron ores, (3) manganiferous silver ores, (4) Manganiferous residuum from zinc roasting. The first three of these are ores; the fourth is a residual product obtained after roasting the zinc from an ore consisting of zinc, iron, and manganese minerals.

MANGANESE ORES.

The only forms of manganese occurring in nature in sufficient quantities to be of commercial value are the oxides, the carbonate, and the silicate. Most manganese ores are oxides, mainly psilomelane and pyrolusite. Other oxides of manganese are mined, but much less abundantly. The carbonate of manganese, rhodochrosite, is not found in sufficient quantities in this country to be commercially valuable, but is mined in several foreign countries, as Spain and Wales. Both the oxides and the carbonate are used in the manufacture of steel and for chemical purposes. The silicate of manganese, rhodonite, contains too much silica to be used for its manganese content, but is sometimes mined for ornamental purposes on account of its beautiful pink color. Other minerals of manganese are too rare to be of commercial value.

OXIDES.

There are many varieties of oxides, but only five of them are important as ores, namely, psilomelane, pyrolusite, braunite, manganite, and wad.

Psilomelane.—Psilomelane ($MnO_2.(Mn, K, Ba)O.nH_2O$; or H_4MnO_5) is a bluish or grayish-black mineral occurring in the amorphous form with a tendency to botryoidal surfaces, concentric structure, and conchoidal fracture. It has a hardness of 5 to 6 and a specific gravity of 3.7 to 4.7. The chemical composition of psilomelane is not definite; the potash, baryta, and water occur in it in varying amounts and are supposed by some mineralogists to be mechanically admixed. The percentage of metallic manganese in psilomelane varies from 45 to 60; that of baryta from 0 to 17, that of potassa from 0 to 5; and that of water from 3 to 6. Psilomelane is abundant in the manganese ores of Vermont, Virginia, Tennessee, Georgia, Arkansas, and California.

Pyrolusite.—Pyrolusite (MnO_2, generally containing a little H_2O) is a grayish-black to black mineral with crystalline or granular structure, belonging to the orthorhombic system of crystallization. It has a hardness of 2 to 2.5, being much softer than psilomelane, and a specific gravity of 4.8. When pure pyrolusite contains 63.2 per cent of metallic manganese, but it is rarely found in the pure state. It generally occurs in association with psilomelane, either lining or filling cavities in it, or occurring in alternating layers with it in botryoidal masses. In such masses it consists of numerous parallel needles arranged perpendicular to the faces of the layers. Locally crystals of pyrolusite are found scattered through masses of psilomelane, the association being generally such as to lead to the conclusion that pyrolusite is an alteration product of psilomelane. It also occurs pseudomorphous after manganite. Pyrolusite is found with psilomelane in the manganese ores of Virginia, Tennessee, and Georgia.

Braunite.—Braunite ($3Mn_2O_3.MnSiO_3$) is a heavy, shiny, brownish or grayish-black mineral, either massive or crystalline, but generally the latter. It crystallizes in the tetragonal system and has a well-developed cleavage. Braunite has a specific gravity of 4.8 and a hardness of 6 to 6.5, being frequently too hard to scratch with a knife. The silica is, by some mineralogists, thought to be present as a mechanical admixture, but some of it, at least, has been proved to be in chemical combination. It varies in quantity from a mere trace to 10 per cent. When pure, braunite contains 69 per cent metallic manganese, but it never occurs so in nature. Braunite is a characteristic mineral in the manganese deposits of Arkansas, where it occurs with psilomelane.

Manganite.—Manganite ($Mn_2O_3.H_2O$) is a heavy, black mineral, massive or crystallizing in the orthorhombic system. It has a hardness of 4 and a specific gravity of 4.2 to 4.4. Manganite has a theoretical content of 62.4 per cent metallic manganese and 10 per cent of water. It is found in this country mainly in California but it is said to occur also in association with psilomelane in Virginia, Georgia, and Arkansas.

Wad.—Wad, an impure mixture of manganese oxides, is a soft, black, earthy mineral occurring with other oxides of manganese, or with manganese carbonates and silicates as an alteration product of these. In the latter case it frequently occurs in the oxidized portions of veins having these minerals as gangue. Dendrite is a branching form of wad.

Bog manganese.—Bog manganese consists of manganese oxides and water, with an admixture of iron oxide, baryta, alumina, and silica, and sometimes nickel and cobalt.

Other oxides.—The remaining oxides of manganese are of small importance as ores, and are rare in this country. The principal ones are hausmannite (Mn_3O_4 or $2MnO.MnO_2$), a brownish-black mineral occurring as tetragonal octahedrons, or in a granular form; polianite (MnO_2), a very pure form of pyrolusite; franklinite ($(Fe,Zn,Mn)O.(Fe,Mn)_2O_3$), a heavy, black mineral occurring in isometric octahedrons; and pelagite ($MnO_2.Fe_2O_3$ with SiO_2, Al_2O_3, and H_2O in mechanical admixture), a deep-sea deposit.

CARBONATES.

Rhodochrosite.—Rhodochrosite ($MnCO_3$) is a pink mineral commonly occurring as a gangue in association with rhodonite in veins traversing granitic rocks. It crystallizes in the hexagonal system, and is frequently found in beautiful rhombohedrons. On exposure it becomes black by oxidation. Rhodochrosite has a specific gravity of 3.45 to 3.6, is soluble in warm hydrochloric acid, and has a hardness of 3.5 to 4.5, being scratched easily by a knife. Its theoretical percentage of metallic manganese is 47.56. The principal occurrences of this mineral in the United States are in New Jersey, Colorado, and Nevada, and at Butte, Mont., in association with ores of silver, lead, copper, and zinc.

Other carbonates.—Other manganiferous carbonates that occur sparingly, are manganocalcite ($(Ca,Mn)CO_3$), manganosiderite ($(Fe,Mn)CO_3$), and ankerite ($(Ca, Mg, Fe, Mn)CO_3$). Manganese occurs also in carbonates of magnesium, zinc, and, rarely, cobalt.

SILICATES AND OTHER MINERALS.

Rhodonite.—Rhodonite ($MnSiO_3$) is a pink mineral that generally occurs as a gangue in ore or pegmatite veins in association with other minerals as quartz and rhodochrosite. It has a triclinic crystallization, a hardness of 5.5 to 6.5, and a specific gravity of 3.4 to 3.7. On exposure it becomes black, like rhodochrosite. This is well illustrated in the oxidized portions of the silver veins at Butte. There, in the lower portions, the gangue is rhodonite and rhodochrosite with quartz, but at the surface the manganese silicate and carbonate are altered to manganese oxides.

Rhodonite contains theoretically 41.9 per cent of metallic manganese. It is frequently found in considerable quantities in veins or lenses in granitic and schistose rocks, but is not commercially valuable on account of its high content of silica. Rhodonite occurs at Blue Hill, Me., in western Massachusetts, in New Jersey, in the Piedmont region, and at various localities in the western United States.

Other silicates.—Other manganese silicates are tephroite (Mn_2SiO_4), a manganese olivine, red to gray in color, and spessartite ($3MnO.Al_2O_3.3SiO_2$), a manganese garnet, pink to brownish red in color.

In a great many of the silicate groups, such as the garnets, amphiboles, pyroxenes, micas, chlorites, olivines, epidotes, zeolites, and others, there are manganese minerals, or admixtures of manganese with other minerals, which are interesting mainly on account of their chemical and mineralogical characters.

Other manganese minerals.—Many other interesting though rare compounds of manganese occur in nature, such as sulphides, sulphates, arsenides, arsenates, antimonates, phosphates, tungstates, borates, titanates, niobates, and tantalates.

TABLE OF MANGANESE MINERALS.

The following manganese minerals have been recognized in nature and described:

Manganese minerals.[a]

Mineral.	Composition.
Oxides:	
Psilomelane	$MnO_2.(Mn,K,Ba)O.nH_2O$ or H_4MnO_5.
Pyrolusite	MnO_2.
Braunite	$3Mn_2O_3.MnSiO_3$.
Manganite	$Mn_2O_3.H_2O$.
Wad	Impure mixture of manganese oxides. Includes bog manganese, asbolite, and lampadite.
Bog manganese	Manganese oxides with oxides of iron, barium, aluminum, silicon, and sometimes nickel and cobalt.
Wackenrodite (peloconite)	Bog manganese with a considerable percentage of lead.
Reissacherite	A variety of bog manganese with a high percentage of water.
Groroilite	A variety of bog manganese.
Lampadite (Lepidophacite)	Cupriferous wad.
Asbolite	Wad with a large percentage of cobalt.
Dendrite	A branching form of wad.
Hausmannite	Mn_3O_4 or $2MnO.MnO_2$.
Polianite	MnO_2. Like pyrolusite chemically, but of different crystallographic form.
Varvicite	An impure pyrolusite derived from the alteration of manganite.
Pyrochroite	$Mn(OH)_2$. White manganese hydrate.
Pelagite	$MnO_2.Fe_2O_3$ with SiO_2, Al_2O_3, and H_2O in mechanical admixture. Found in the deep sea.
Halobolite	Similar to pelagite. Found in the deep sea.
Dysluite	$(Zn,Fe,Mn)O.(Al,Fe)_2O_3$. Zinc - manganese - iron gahnite (spinel).
Franklinite	$(Fe,Zn,Mn)O.(Fe,Mn)_2O_3$.
Chalcophanite	$(Mn,Zn)O.2MnO_2.2H_2O$. A decomposition product of franklinite.
Manganbrucite	Brucite ($MgO.H_2O$) with considerable manganese.
Manganomagnetite	Magnetite (Fe_3O_4) with 4 to 6 per cent manganese.

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[a] Compiled from Dana, E. S., System of mineralogy; Palache, Charles, Franklin Furnace folio (No. 161), Geol. Atlas U. S., U. S. Geol. Survey, 1909, pp. 89-110; and other sources.

Mineral.	Composition.
Oxides—Continued.	
Bixbyite	$FeO.MnO_2$.
Crednerite	$3CuO.2Mn_2O_3$.
Jacobsite	$(Mn,Mg)O.(Fe,Mn)_2O_3$.
Hetærolite	$ZnO.Mn_2O_3.H_2O$(?). A zinc-bearing hausmannite.
Manganosite	MnO.
Zincite (manganiferous)	(Zn,Mn)O.
Carbonates:	
Rhodochrosite	$MnCO_3$.
Manganocalcite (calcimangite, spartaite)	$(Ca,Mn)CO_3$. Calcite ($CaCO_3$) with varying amounts of manganese.
Manganosiderite	$(Fe,Mn)CO_3$.
Ankerite	$(Ca,Mg,Fe,Mn)CO_3$.
Silicates:	
Rhodonite	$MnSiO_3$. Manganese metasilicate.
Bustamite	$(Mn,Ca)SiO_3.nCaCO_3$. Manganese-calcium metasilicate.
Ferrorhodonite	$(Mn,Fe)SiO_3$. Manganese-iron metasilicate.
Fowlerite	$(Mn,Zn,Fe,Ca)SiO_3$. Manganese-zinc metasilicate.
Hydrorhodonite	Alteration product from rhodonite to serpentine.
Leucophoenicite	$H_2(Mn,Zn,Ca)_7Si_3O_{14}$.
Glaucochroite	$CaMnSiO_4$.
Tephroite	Mn_2SiO_4. Manganese olivine.
Knebelite	$(Fe,Mn)_2SiO_4$. Manganiferous olivines.
Hortonolite	$(Fe,Mg,Mn)_2SiO_4$.
Rœpperite	Zinc-bearing tephroite.
Helvite	$(Gl,Mn,Fe)_7Si_3O_{12}S$ or $3(Gl,Mn,Fe)_2SiO_4(Mn,Fe)S$.
Danalite	$(Gl,Fe,Zn,Mn)_7Si_3O_{12}S$.
Friedelite	$H_7(Mn,Cl)Mn_4Si_4O_{16}$ (Groth). $H_7(Mn,Cl)Mn_4(SiO_4)$ (Palache).
Pyrosmalite	$H_7((Fe,Mn)Cl)(Fe,Mn)_4Si_4O_{16}$.
Trimerite	$(Mn,Ca)_2SiO_4.Gl_2SiO_4$.
Spessartite	$Mn_3Al_2(SiO_4)_2$. Manganese-aluminum garnet.
Rothoffite (polyadelphite)	Manganese-calcium-iron garnet. Manganiferous andradite ($Ca_3Fe_2(SiO_4)_3$). (Polyadelphite $(Ca,Mn)_3(Fe,Al)_2Si_3O_2$).
Manganpectolite	Pectolite ($HNaCa_2(SiO_3)_3$), with 4 per cent of MnO.
Willemite (manganiferous)	$(Zn,Mn)_2SiO_4$. Troostite and tephrowillemite are varieties of willemite rich in manganese.
Manganchlorite	Clinochlore ($H_8Mg_5Al_2Si_3O_{18}$) with 2.3 per cent MnO.
Piedmontite	Epidote ($HCa_2(Al,Fe)_3Si_3O_{13}$) with 5 to 15 per cent Mn_2O_3.
Manganophyllite	Biotite with considerable manganese.
Dannemorite	Iron-manganese amphibole.
Hornblende (manganiferous).	
Richterite	$(K_2,Na_2,Mg,Ca,Mn)_4(SiO_3)_4$. Sodium-magnesium-manganese amphibole.
Edenite (manganiferous)	Aluminous calcium-magnesium amphibole with manganese.
Arfvedsonite (manganiferous)	Sodium-calcium, ferrous iron metasilicate with manganese.

Mineral.	Composition.	
Silicates—Continued.		
Manganhedenbergite	Hedenbergite ($CaFe(SiO_3)_2$), calcium-iron pyroxene, with 6.5 per cent manganese.	
Schefferite	$6CaMgSi_2O_6.MgFeSi_2O_6.Mn_2Si_2O_6$. Manganese pyroxene.	
Jeffersonite	Manganese, zinc pyroxene.	
Hancockite	$H_2(Pb,Ca,Sr,Mn)_4(Al,Fe,Mn)_6Si_6O_{26}$.	
Babingtonite	$(Ca,Fe,Mn)SiO_3$ with $Fe_2(SiO_3)_3$.	
Staurolite (manganiferous)	$H_2O.2FeO.5Al_2O_3.4SiO_2$ with manganese.	
Manganandalusite	Manganiferous andalusite ($AlSiO_5$).	
Ilvaite (manganiferous)	Calcium-iron silicate with manganese.	
Ardennite	Aluminum-manganese vanadio silicate.	
Carpholite	$H_4MnAl_2Si_2O_{10}$.	
Inesite	$2(Mn,Ca).SiO_3.H_2O$. Manganiferous zeolite.	
Ganophyllite	$6H_2O.7MnO.Al_2O_3.8SiO_2$. Manganiferous zeolite.	
Axinite	$(Ca,Mn,Fe)_7Al_4B_2(SiO_4)_8$.	
Bementite	$2MnSiO_3.H_2O$.	
Caryopilite	$4MnO.3SiO_2.3H_2O$.	
Neotocite	Hydrated iron-manganese silicate.	
Miscellaneous:		
Alabandite	MnS. Manganese monosulphide.	
Hauerite	MnS_2. Manganese disulphide.	
Fluorite (manganiferous)	CaF_2 with manganese.	
Apjohnite (bosjemanite)	$MnSO_4.Al_2(SO_4)_3+24H_2O$.	Manganese sulphates.
Fauserite	$2MnSO_4.MgSO_4+15H_2O$.	
Szmikite	$MnSO_4+H_2O$.	
Mallardite	$MnSO_4+7H_2O$.	
Kaneite	Mn_5As_4. Manganese arsenide.	
Chondrarsenite	$Mn_3As_2O_8.3Mn(OH)_2$. Manganese arsenate.	
Xantharsenite	Near chondrarsenite, but contains more water.	
Sarkinite	$Mn(OH)_2.Mn_3As_2O_8$.	Manganese arsenates.
Allactite	$Mn_3As_2O_8.4Mn(OH)_2$.	
Synadelphite	$2(Al,Mn)AsO_4.5Mn(OH)_2$.	
Flinkite	$MnAsO_4.2Mn(OH)_2$.	
Hematolite	$(Al,Mn)AsO_4.4Mn(OH)_2$.	
Arseniopleite	Calcium-manganese arsenate.	
Manganostibiite	Basic manganese antimonate.	
Retzian	Basic arsenate of yttrium earths, manganese and calcium.	
Triphylite	$Li(Fe,Mn)PO_4$. Lithium-iron-manganese phosphate.	
Lithiophilite	$Li(Mn,Fe)PO_4$. Lithium-manganese-iron phosphate.	
Natrophilite	$Na,MnPO_4$. Sodium-manganese phosphate.	
Hureaulite	Manganese phosphate.	
Dickinsonite	Chiefly Mn,Fe,Na hydrated phosphate.	
Reddingite	$(Mn,Fe)_3(PO_4)_2.3H_2O$.	
Manganapatite	$[(Ca,Mn)F]Ca_4(PO_4)_3$. Apatite with manganese replacing calcium to 10.5 per cent MnO.	
Fairfieldite (leucomanganite)	$(MnCa)_3(PO_4)_2.2H_2O$.	
Triplite	Iron-manganese-calcium-magnesium phosphate.	
Wolframite	$(Fe,Mn)WO_4$. Iron-manganese tungstate.	

Mineral.	Composition.
Miscellaneous—Continued.	
Hübnerite	Near wolframite but containing 20–25 per cent MnO.
Pinakiolite	$3MgO.B_2O_3+MnO.Mn_2O_3$. Manganese-magnesium borate.
Sussexite	$H(Mn,Zn,Mg)BO_3$.
Pyrophanite	$MnTiO_3$. Manganese titanate.
Columbite-tantalite	$(Fe,Mn)(Nb,Ta)_2O_6$. Iron-manganese columbate and tantalate.
Manganocolumbite-Manganotantalite.	$(Mn,Fe)(Nb,Ta)_2O_6$. Manganese-iron columbate and tantalate.

MANGANESE IN THE DEEP SEA.

Manganese oxides occur locally in the deep sea in the form of concretions and nodules,[a] to which the names pelagite and halobolite have been given. During the *Challenger* expedition[a] these were found in many parts of the Pacific Ocean in deep-sea red clay at depths of about 2,220 fathoms. They were especially abundant between Hawaii and Japan, where locally the floor of the sea was covered with these potato-like concretions associated with pumice and red clay. The concretions are made up of concentric layers, thin on the outside but coarser in the interior, and many of them contain fragments of pumice, shark's teeth, mollusk shells, coral, and other materials.

The nodules vary considerably in composition, the percentage of ferric oxide ranging up to 40 and that of manganese dioxide up to 55, the one being low when the other is high. Silica, alumina, and lime are present in considerable quantities.

The following are analyses of deep-sea manganese concretions, No. 1 by Schwager, Nos. 2 and 3 from the *Challenger* report.

Analyses of deep-sea manganese concretions.

	1.		2.	3.
Fe_2O_3	27.46	Fe_2O_3	6.78	41.39
MnO_2	23.60	Loss by ignition	55.67	22.80
H_2O	17.82	MnO_2	11.80	18.30
SiO_2	16.03	SiO_2	14.10	6.66
Al_2O_3	10.21	Al_2O_3	3.00	2.25
Na_2O	2.36	$CaCO_3$	5.57	5.15
Cl	.94	$CaSO_4$	.58	1.17
CaO	.92	$Ca_3 2PO_4$	Trace.	.34
TiO_2	.66	$MgCO_3$	1.90	1.51
SO_3	.48	CuNiCr	Trace.	Trace.
K_2O	.40	CaO	.49	.25
MgO	.18	MgO	.11	.18
CO_2	.05			
P_2O_5	.02			
CuO	.02			
CoO,NiO	.01			
BaO	.009			
Li, Pb, Sb, B, I	Trace.			
Organic matter	Trace.			
	101.17			

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[a] Deep-sea deposits: Rept. Scientific Results Voy. H. M. S. *Challenger*, 1873–1876, p. 341; also, Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, 1. Hälfte, p. 261.

The *Gazelle*,[a] during its expedition, found manganese concretions in many places in the Pacific Ocean, but in greatest abundance near Cook Island. Chun[b] speaks of the occurrence of manganiferous iron concretions, some of which are as large as 8 centimeters in diameter, in the southern Atlantic Ocean, at a depth of 6,700 meters. Andrussow[c] mentions the occurrence of similar concretions in the Black Sea.

Gümbel believes that deep-sea manganese concretions find their origin in subterranean volcanic eruptions, and that they originate by the accumulation of manganese and iron oxides on the sea bottom without any additions from organisms.

MANGANIFEROUS IRON ORES.

Manganiferous iron ores consist of a mixture of iron and manganese oxides in varying proportions. The iron is generally in the form of limonite, as in the manganiferous iron ores of the Appalachian region, though frequently it occurs as hematite, as in the Lake Superior ores. The manganese is mostly in the form of psilomelane, though pyrolusite is often abundant. Rarely iron oxides and manganese carbonate are associated, as at Chevron, Belgium, and in Wales. The manganese and iron oxides may occur together as a coarse mixture easily separated, or they may be so closely associated as to be indistinguishable to the eye. In most deposits where the individual oxides may be recognized the manganese seems to have penetrated into the mass, while the iron is nearer the surface. Small masses of psilomelane are frequently found in the interior of limonite nodules, and limonite is found lining cavities in manganese ores. The two oxides may be so intermixed, however, that there seems to be no definite relation between them. In some iron-ore deposits there are portions in which pockets of manganese ore occur, while the rest of the body may be pure iron ore. In many manganese deposits the upper portion is ferruginous, containing limonite as surface coatings or intimately mixed with the manganese ore.

The amount of metallic manganese in manganiferous iron ore varies from less than 1 per cent to 40 per cent or more. The high and medium grades of ore are used in the manufacture of spiegeleisen and ferromanganese, but the ore that contains only a small percentage of manganese is not used for this metal, but for its iron only. High-grade manganiferous iron ore is found in the Appalachian and New England regions; low-grade ore occurs in the same regions and also in the Lake Superior district and in Arkansas.

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[a] Gümbel, K. W. von, Forschungsreise S. M. S. *Gazelle*, II. Teil, pp. 33–36.

[b] Chun, Carl, Aus den Tiefen des Weltmeeres: Schilderungen von der deutschen Tiefsee Expedition, 1903, pp. 162–63.

[c] Andrussow, N., Guide des excursions du VII Congrès géol. internat., 1897, XXIX, p. 13.

MANGANIFEROUS SILVER ORES.

Manganiferous silver ores occur abundantly in the oxidized portions of many of the silver deposits of western United States. They consist of manganese and iron oxides, carrying silver chloride and lead carbonate. The iron and manganese are intimately associated, forming a black amorphous ore. The iron is probably in the form of limonite and the manganese in the form of wad. As a rule, iron oxide predominates over manganese oxide, though locally, as at Butte, it is almost entirely absent. The lead sometimes occurs partly as the unaltered sulphide.

The unoxidized ores from which these ores are derived consist of silver, lead, zinc, and iron sulphides in a gangue of quartz, which in some places, as at Butte, is mixed with manganese carbonate and silicate. In other places, as at Leadville, manganese minerals are altogether lacking in the unoxidized ore, though they are abundant in the oxidized product. Zinc is rarely present in the oxidized zone, being readily dissolved and carried downward. Gold occurs in small quantities locally.

With regard to use, manganiferous silver ores may be classed under three heads:

(1) Ores with a high percentage of silver and lead and used for these metals only. The manganese and iron oxides present are a valuable aid in fluxing, and such ores as contain considerable quantities of them draw higher prices than other silver ores with the same silver content.

(2) Ores that are low in silver and lead but contain a large quantity of iron and manganese are utilized in the manufacture of spiegeleisen and ferromanganese. Under this head there may be included as a subclass ores that are too low in manganese to be used as a source for iron-manganese alloys and that are used for their iron content only.

(3) Ores that are too low in silver and lead to be used directly as a source of these metals and too low in iron and manganese to be used for the manufacture of spiegeleisen and ferromanganese are sent to the smelters to be used for fluxing purposes on account of their content of iron and manganese oxides. The silver and lead present, however, are recovered during the smelting, while the iron and manganese pass into the slag and are lost.

Ores of the first and third classes are mined in many silver districts of the West; those of the second class have been shipped only from the Leadville district.

MANGANIFEROUS ZINC RESIDUUM.

Manganiferous zinc residuum consists essentially of a mixture of iron and manganese oxides in various proportions. The ore from which it is obtained is a mixture of franklinite, willemite, and zincite, the first predominating. Tephroite and rhodonite are present in some ores and calcite forms the gangue. During the roasting the zinc is removed as zinc oxide, while the oxides of the other metals—that is, iron and manganese—remain as a waste product. This material has been used for the manufacture of spiegeleisen since 1870. It is obtained only from zinc works treating New Jersey zinc ores.

CHAPTER II.

MANGANESE DEPOSITS OF THE UNITED STATES.

NEW ENGLAND REGION AND NEW YORK.

NEW ENGLAND CRYSTALLINE AREA.

Manganese deposits occur in New England in both crystalline and sedimentary areas. Those in the crystalline area consist principally of rhodonite, but include some deposits of wad, probably derived from it. The deposits of this nature are scattered and are too small to be of any importance. Among the best known are the rhodonite at Blue Hill, Me., said to have been mined for fluxing purposes, and that at Cummington, Mass., mined for ornaments and for jewelry on account of its beautiful pink color. At Blue Hill[a] the rhodonite occurs in a vein 15 feet wide running east-northeast by west-southwest through a hill of contorted gneiss; at Cummington it occurs in Emerson's[b] Conway schist, of Silurian age, about 1 mile west of the town. Impure mixtures of rhodonite and wad occur near Winchester and Hinsdale, N. H.,[c] at Plainfield, Conway,[c] Chesterfield,[d] Sheffield,[e] and other localities in Massachusetts, and at Sneech Pond[f] and Pawtucket in Rhode Island. Deposits of bog manganese occur in Knox and Oxford counties, Me.

Analyses of manganese ore from the New England crystalline area are given below:

Analyses of manganese ore from Blue Hill, Me.[a]

	1.	2.	3.
MnO	35.13	29.72	15.00
FeO	14.01	24.31	12.00
Al_2O_3	7.45	3.04	....
CaO	3.49	5.02	....
P_2O_5	1.02	....	....
SiO_2	35.84	35.70	39.00
Mn	27.20	23.02	11.62
Fe	10.90	19.37	9.33
P	.45	....	....

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[a] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 416.

[b] Emerson, B. K., Holyoke folio (No. 50), Geol. Atlas U. S., U. S. Geol. Survey, 1898, p. 2.

[c] Hitchcock, Edward, Report on the geology of Massachusetts: Am. Jour. Sci., 1st ser., vol. 22, 1832, p. 61.

[d] Mead, William, Localities of minerals: Am. Jour. Sci., 1st ser., vol. 7, 1834, p. 54.

[e] Am. Jour. Sci., 1st ser., vol. 4, 1822, p. 189.

[f] Jackson, C. T., Am. Jour Sci., 1st ser., vol. 40, p. 185.

Analysis of manganese ore from Sneech Pond, Rhode Island.[a]

MnO	32.8
FeO	35.9
SiO_2	26.4
CO_2	5.2
	100.3
Mn	25.7
Fe	27.9

NEW ENGLAND SEDIMENTARY AREA.

GENERAL STATEMENT.

Manganese ores associated with sedimentary rocks occur in western New England together with the iron-ore deposits. Small quantities of manganese ore are present in most of the brown iron ore deposits in this region and in a few of them it is present in sufficient amount to form a manganiferous iron ore, as in Vermont. Even in Vermont, however, the larger part of the deposits is brown iron ore.

The manganese ore occurs as kidneys and irregular pockets in clay. The kidneys are scattered through clay beds in association with fragments of brown iron ore, or occur separately. They are composed mainly of black psilomelane with nests of pyrolusite. The ore in the pockets consists of a mixture of psilomelane and pyrolusite. In some pockets pure manganese ore occurs; in others manganese and iron ores are mixed in all proportions. Such mixed iron and manganese deposits occur at Redding, Salisbury, and elsewhere in western Connecticut; in the Berkshire Hills and southward in western Massachusetts; and at Brandon, South Wallingford, Chittenden, and many other localities in Vermont.

VERMONT.

The deposits at Brandon and South Wallingford[b] occur in Otter Creek valley near the base of the west slope of the Green Mountains. Otter Creek flows northward through this valley, emptying into Lake Champlain. To the east of it are the Green Mountains and to the west are various minor ranges.

The rock forming the lower ridges on the west slope of the Green Mountains is a vitreous Cambrian quartzite; that underlying the valley is a massive or semicrystalline Cambrian limestone of later age. Both have a general north-south strike and a nearly vertical dip. East of the quartzite and forming the main part of the Green Mountains are earlier metamorphic rocks, while west of the valley are fossiliferous rocks of Ordovician and Silurian age.

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[a] Jackson, C. T., loc. cit.

[b] Penrose, R. A. F., jr., Manganese: Its uses, ores, and deposits: Ann. Rept. Arkansas Geol. Survey for 1890, vol. 1, p. 391.

At South Wallingford the ores are found in a clay layer at the contact of the Cambrian quartzite and limestone. (See fig. 1.) This layer has a general north-south direction and a nearly vertical dip. The deposit consists of associated iron and manganese ores, occurring in pockets and nests, in yellow, red, gray, or white clay. The ores of iron and manganese may be in separate pockets or may occur together in the same pocket, mixed in all proportions. The clay bed has a probable average thickness of several hundred feet, and ore is scattered through this at intervals. The deposit is overlain by 10 to 60 feet of glacial drift. The iron ore is limonite; the manganese ore consists of massive psilomelane, crystalline pyrolusite, and probably some manganite. The massive ore occurs mainly in the form of geodes; the crystalline ore, in general, lines cavities in the massive ore.

The deposit near Brandon is in a small tributary valley at a point several miles east of the main Otter Creek valley. It consists of iron ore containing manganese ore in subordinate quantities. The ores occur in a brown and white clay that occupies the bottom of the tributary valley. To the east are ridges of quartzite; to the west is white dolomitic limestone. The clay bed overlies their contact, and is in turn overlain by glacial deposits. Fossil plants and fruits of Tertiary (probably Miocene) age have been discovered in lignite in a similar clay bed in the same locality. This makes it probable that the iron and manganese bearing clay is a Tertiary deposit derived from an underlying clay layer similar in position to that containing the South Wallingford ores.

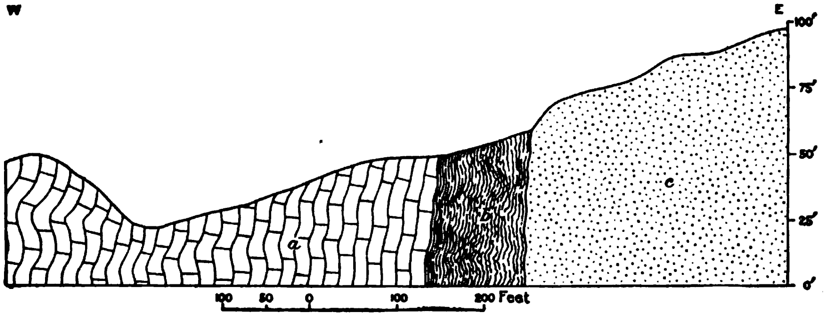

FIGURE 1.—Section through the South Wallingford (Vt.) ore deposit, showing the occurrence of the manganese-bearing clay. (After Penrose.) *a*, Limestone; *b* manganese-bearing clay; *c*, quartzite.

The manganese ore occurs in nodules and in irregular masses, ranging in size from a fraction of an inch to 12 inches or more in diameter. Its characteristic form, however, is that of small kidney-shaped nodules a few inches in diameter, of massive texture, and of steel-blue or black color—probably psilomelane. Many of the larger masses contain cavities lined with crystalline pyrolusite. Some of the ore shows concretionary structure. The iron ore is limonite, and the manganese and associated iron ore are concentrated in pockets or scattered irregularly through the clay.

Manganese and manganiferous iron ores have been reported from many other localities in Vermont,[a] among which are Bennington and Stamford, Bennington County; Pittsford and Chittenden, Rutland County; Plymouth, Windsor County; Topsham, Orange County; Bristol and Monkton, Addison County; Colchester, Chittenden County; and Irasburg and Coventry, Orleans County.

The following are analyses of manganese ore and manganiferous iron ore from Vermont.[b]

Analyses of manganese ores and manganiferous iron ores from Vermont.

	1.	2.	3.	4.	5.	6.
Mn	44.107	35.00	48.778	58.62	20.369	19.706
O				27.72		
Fe	7.18	25.00	4.97		31.648	29.268
SiO_2	9.23	3.10	7.90	3.60	12.770	14.000
P		.061	.111		.125	.145
Moisture				9.75	5.000	8.000

1, 2, 3. Manganese ore from South Wallingford.
4. Manganese ore from Brandon.
5, 6. Manganiferous iron ore from Vermont.

NEW YORK.

Small deposits of manganese ore, mainly in the form of wad and bog manganese, are distributed through various parts of New York, being most numerous in the southeastern part. No ores, however, have been shipped from this State.

Manganese ores[c] occur in the eastern part of the State at Austerlitz, Hillsdale, and Canaan Center, Columbia County; At Unionvale, Dutchess County; near Sing Sing, Westchester County; near Warwick, Orange County; near Keeseville, Essex County, and in New York, Albany, Warren, and Rensselaer counties. In the north-central part they are found at Tug Hill, near Houseville, Lewis County; in the western part small deposits are found in Conewango and Little valleys, and near Randolph, Cattaraugus County, and in Allegany County.

The deposits of Columbia County consist of beds of wad on low ground below a slate ridge. In the slates are veins of quartz containing brown spar composed of lime and magnesia and oxides of iron and manganese, the solution and redeposition of which forms the deposits.

At Unionvale a crystalline gray oxide of manganese is found in geodes in brown iron ore. It has the following composition:

Mn oxides	83.33
Fe oxides and Al_2O_3	6.16
H_2O	10.00

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[a] Geology of Vermont, 1861, p. 811.

[b] Penrose, R. A. F., jr., op. cit., pp. 395, 398.

[c] Beck, L. C., Nat. Hist. New York, Div. III, Mineralogy, 1842, pp. 53-54 and 406-407.

Near Sing Sing the manganese occurs in dolomite as nodules of black oxide with a trace of copper; near Warwick as a black oxide mixed with iron ores. In Warren and Essex counties it occurs as a mixture of rhodonite and wad. At Tug Hill in Lewis County manganese occurs as a bed of earthy oxide in a marsh. In Cattaraugus and Allegany counties the black oxide is found scattered through the surface soil in grains and fragments ranging in size from that of shot to that of a walnut.

The following analyses show the composition of manganese and manganiferous iron ores from New York:

Analyses of manganese ore and manganiferous iron ore from New York.[a]

	1.	2.	3.	4.	5.	6.	7.
MnO_2	68.50	58.50	50.50	53.00	33.40	11.45	26.66
Fe_2O_3	16.75	22.00	24.50	32.15	34.10	28.20	6.00
SiO_2 and Al_2O_3	3.25	2.50	4.50	6.90	8.75	44.75	57.50
H_2O	11.50	17.00	20.50	6.85	24.00	15.60	9.83

[a] Beck, L. S., op. cit., p. 55.

1. From Hillsdale, Columbia County.
2. From Austerlitz, Columbia County.
3. From Canaan Center, Columbia County.
4. From Sing Sing, Westchester County.
5. From Keeseville, Essex County.
6. From Tug Hill, Lewis County.
7. From Warwick, Orange County.

COMMERCIAL IMPORTANCE OF THE ORES.

The manganese deposits of New England and New York are of very little commercial importance, and no manganese ore is being produced here at present. A small amount of rhodonite has been mined in western Massachusetts and used for ornamental purposes, and manganiferous iron ore has been shipped from the South Wallingford, Brandon, and Chittenden districts in Vermont, and from Salisbury, Conn. The Vermont ores were used for their manganese content, but the Salisbury ores were used largely for their iron content. A mixture of rhodonite and wad is said to have been mined at Blue Hill, Me., and used for fluxing in the Katahdin furnaces. New York has never produced manganese ores.

The Vermont deposits are the only ones to which any importance can be attached. They are of considerable extent and may be expected to yield a fair supply of ore for use in the manufacture of spiegeleisen.

PIEDMONT REGION AND COASTAL PLAIN.

GENERAL STATEMENT.

The Piedmont region, as here treated, comprises a belt of territory underlain by crystalline rocks, extending from New Jersey to Alabama. In the northern half it contains considerable areas of Triassic trap and sandstone that conceal the underlying crystalline rocks and also a few areas of Paleozoic sediments. It is bounded on the east by the fall line, which marks the contact between the crystalline rocks and the Mesozoic sediments of the Coastal Plain, and on the west by the Appalachian Mountains. In Virginia the Blue Ridge marks the contact between the crystalline rocks of the Piedmont region and the Paleozoic sediments of the Appalachian Valley belt. Farther north the boundary is somewhat indefinite, for the Paleozoic rocks extend southoastward beyond the front ranges of the Appalachians. Southward from Virginia the crystalline rocks extend west of the Blue Ridge into the Appalachian Mountains. All the manganese deposits in the crystalline and metamorphic rocks will be described as in the Piedmont region.

East of the Piedmont region is the Coastal Plain, which occupies a belt of territory lying parallel to the Piedmont region and extending eastward from it to the Atlantic Ocean. It is underlain by sediments, largely unconsolidated, of Mesozoic and Cenozoic age.

Manganese ores occur in the Piedmont region from New Jersey to Georgia, the principal deposits being in the James River-Staunton River region, in Virginia; between Kings Mountain and Blacksburg on the boundary of North Carolina and South Carolina; and near McCormick, S. C. Minor deposits occur at Mount Airy, Bowersville, and Draketown, Ga.,[a] and in other parts of South Carolina, North Carolina, and Virginia.

As far as known only one small deposit of manganese ore has been found on the Coastal Plain—in Tertiary rocks near City Point, Prince George County, Va., in association with iron ores. Several hundred tons of ore are said to have been mined.[b]

Manganiferous zinc ores occur at Franklin Furnace and Ogdensburg, Sussex County, N. J., and manganiferous iron ores are found in small quantities at various localities in the Piedmont region.

The rocks of the Piedmont Plateau are ancient crystallines and metamorphics, in many places so altered that their original character is indistinguishable. The main types are schists, granites, and gneisses, with which are associated smaller amounts of slates, quartzites, and crystalline limestones. These are intricately folded, faulted, and metamorphosed and form a basement into which dikes and masses of gabbro, diabase, and diorite have been intruded.

All of these rocks have suffered considerable disintegration and decomposition, the weathered zone in some places reaching to a depth of 150 feet or more. It is in this zone that the manganese deposits occur. Generally the surface material consists of unconsolidated sands and clays that retain to a marked degree the structure of the original rocks and contain the original rock materials, such as flakes of mica and fragments of quartz and feldspar. The weathering is rarely so complete as to obliterate structures and textures entirely. Hard masses of less easily disintegrated rock are imbedded in the clay and sand, and at many places relatively solid layers of granite are found between soft, decomposed layers of mica schist.

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[a] Watson, Thomas L., Preliminary report on the manganese deposits of Georgia: Bull. Georgia Geol. Survey No. 14, pp. 158 et seq.

[b] Weeks, J. D., Mineral Resources U. S. for 1885, p. 309.

FRANKLIN FURNACE, N. J.

Deposits of manganiferous zinc ores occur at Mine Hill (Franklin Furnace) and Sterling Hill (Ogdensburg), Sussex County, N. J.[a] These two deposits, which are about 3 miles apart, occur as bands in white crystalline limestone, associated with bands of gneiss. Both limestone and gneiss are intruded by masses of later granitoid gneiss and by pegmatite lenses and trap dikes.

The ore band at Mine Hill is closely associated with the gneiss both in position and structure, being only 30 feet from the boundary of a gneiss band on the west and outcropping parallel to it in a northeast-southwest direction for 2,600 feet. At its northeast end it disappears under Paleozoic sediments. At its southwest end it turns sharply to the northeast and continues in this direction nearly parallel to the main band for 600 feet, when it disappears from the surface, but continues underground for a distance of 1,000 feet or more. The deposit is in the form of a northward-pitching trough with limbs of unequal height, the elbow at the south end being formed where the bottom of the trough comes to the surface. The west limb has an average dip of 55° to the east and a maximum depth along this dip of 1,350 feet at a point near its northernmost outcrop. The east limb has a nearly vertical dip, though locally it dips steeply to the east. It has a maximum height of 300 feet at a point just north of the place where it disappears from the surface. North of this point it gradually shortens and at length disappears and only the west limb remains. The ore body varies in width from 12 to 100 feet, the average width of the west limb being 70 feet and that of the east limb 35 feet.

The deposit at Sterling Hill is also in the form of a northeastward-pitching trough, causing the ore band to outcrop in a hook, both ends of which strike northeast. The west limb outcrops for a distance of 600 feet and the east limb for 1,500 feet from the turn of the hook. Both limbs dip to the southeast at angles ranging from 45° to 60°. They vary in thickness from 10 to 30 feet.

The ores consist principally of zincite (red oxide of zinc (ZnO)), willemite (silicate of zinc (Zn_2SiO_4)), and franklinite ($(Fe,Zn,Mn)O.(Fe,Mn)_2O_3$), associated locally with tephroite (Mn_2SiO_4) and rhodonite

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[a] Spencer, A. C., Franklin Furnace folio (No. 161), Geol. Atlas U. S., U. S. Geol. Survey, 1908, p. 24. Wolff, J. E., Zinc and manganese deposits of Franklin Furnace, N. J.: Bull. U. S. Geol. Survey No. 213, 1903, p. 214.

($MnSiO_3$) in small quantities. Zincite, franklinite, and willemite have the following metalliferous content, from which it will be seen that all contain some manganese:

Metalliferous content of ores from Franklin Furnace, N. J.

	Zincite.	Willemite.	Franklinite.
Mn	[a] 5	1½–3	10–19
Zn	77	58	6–18
Fe		1½–3	39–47

[a] Includes some iron.

Zincite, willemite, and franklinite occur in varying proportions, sometimes one, sometimes another, being predominant. Calcite is associated with them in considerable quantities as gangue. Garnet is frequently present.

Locally the veins consist entirely of franklinite, while elsewhere this is associated with willemite or zincite, or both. In still other places zincite only is present, occurring in rounded grains or bunches in coarsely crystalline calcite.

The following are estimates of the average mineral composition of zinc ore from Mine Hill:

Mineral composition of zinc ore from Mine Hill.

[1, Ulke; 2, 3, Ricketts.]

	1.	2.	3.
Franklinite	51.92	48.20	51.50
Willemite	31.58	28.10	20.23
Zincite	.52	2.70	6.40
Carbonates	12.67	11.32	10.00
Silicates	3.31	9.50	11.13
	100.00	99.82	99.26

The minerals occur in different forms and sizes—in small flattened lenses, in which the ore shows fine banding or foliation, or in shotlike aggregates. In some places large crystals, 1 to 2 inches in diameter, of zincite or franklinite, are scattered through coarse calcite like a pudding stone. None of the minerals have very distinct crystal faces, although franklinite has a tendency to assume an octahedral form. The minerals appear to be of contemporaneous origin, for each is found inclosed in the other.

From their structure it appears that the ore deposits assumed their present form at the same time as the associated limestone, in which they were probably originally segregated in some other form. They are also closely related to the gneisses.

The following are analyses of New Jersey zinc ore:

Analyses of New Jersey zinc ore.[a]

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	10.21	9.91	11.08	10.28	10.33	4.86	4.43	5.15	11.77	9.78
Fe_2O_3	31.41	31.63	27.54	30.46	30.36	30.33	30.13	27.62	30.91	27.20
MnO	15.84	16.46	17.63	15.66	15.95	12.30	12.21	13.09	10.27	17.81
ZnO	32.83	34.07	35.88	27.15	26.34	29.42	27.12	23.38	25.71	22.94
Al_2O_3	.21	.80	.24	.09	1.16	.67	....	.64	2.01	.67
CaO	5.09	4.08	2.01	8.45	7.15	12.65	12.63	14.37	10.43	11.46
MgO	....	.21	.77	.91	1.09	....	1.69	1.98	.99	.74
Fe	21.98	22.14	19.28	21.32	21.25	21.23	21.09	19.33	....	19.04
Mn	12.27	12.75	13.60	12.12	12.35	9.53	9.46	11.13	....	13.79
Zn	26.34	27.34	28.78	21.79	21.14	23.61	21.76	18.76	....	18.41

[a] Weeks, J. D., Manganese: Eleventh Census U. S., Mineral Industries, p. 324; also Mineral Resources U. S. for 1885, p. 337.

1, 2, 3, 4, 5, 9, and 10. Ore from Mine Hill.
6, 7, 8. Ore from Sterling Hill.

The ore taken from the mines is crushed and treated with magnetic separators, which yield three products, known as (1) franklinite (2) half-and-half, and (3) willemite. The first product is largely franklinite and is used in the preparation of zinc white (zinc oxide). The residuum left after the zinc is volatilized is used in blast furnaces for the manufacture of spiegeleisen. The second product consists of franklinite, rhodonite, garnet, and other silicates with attached particles of richer zinc minerals. This product also is used in preparing zinc white, but the residuum contains too much silica to be used in the manufacture of spiegeleisen. The third product consists of willemite and zincite with calcite and silicates as impurities. The calcite is removed by means of jigs and concentrating tables and the resulting product is used in making high-grade spelter.

The ores used in the manufacture of zinc white are mixed with anthracite and spread over a thin layer of finely powdered anthracite in the volatilizing and oxidizing furnace. Rarely a flux, dolomite, is used with the half-and-half ore, but never with the franklinite ore. After the furnace is charged an underblast is applied which ignites the lower layer of anthracite and heats the mixture above it. The anthracite mixed with the ore reduces it to metallic zinc, which is volatilized by the heat. The zinc vapor is immediately oxidized and, together with the gasses of combustion, is drawn from the furnace by flues and collected in bags as zinc oxide (ZnO).

The residuum or clinker from the franklinite product, consisting largely of manganese and iron oxides, is sent to the blast furnace to be used in the manufacture of spiegeleisen. It is, of course, richer in manganese and iron than the ores, but still contains considerable impurities derived from both ore and anthracite. The clinker is partly in the form of flat cakes about 2 inches thick and 4 to 10 inches in diameter, and partly in small fragments ranging in size from that of dust to pieces 2 inches in diameter. Only the coarse fragments are utilized in the manufacture of spiegeleisen, the fine material being sifted out. When a low-grade spiegeleisen is desired, the clinker is mixed with iron ore in the blast furnaces, but usually the clinker alone is used.

The following are average analyses of the manganiferous zinc residuum now produced by the New Jersey Zinc Company:

Analyses of manganiferous zinc residuum.

[By the New Jersey Zinc Company.]

Mn	13.80	12.71	12.96	12.52	12.42
Fe	40.68	37.66	38.81	39.33	37.70
SiO_2	12.08	12.73	13.01	14.17	14.75

Before the installation of the magnetic separators a rough mixture of the ore was used in the zinc oxide furnaces together with anthracite and limestone. The resulting clinker was much more impure and contained almost twice as much silica as the present product.

The following are analyses of various types of clinkers produced by the old methods:

Analyses of clinker from zinc oxide furnaces.[a]

SiO_2	19.97	25.02	23.47	18.14	21.29
Fe_2O_3	33.21	31.06	33.84	36.16	31.06
Al_2O_3	2.25	6.36	8.24	6.94	5.98
MnO	17.83	16.22	15.66	18.90	21.03
CaO	11.96	10.73	11.04	11.81	7.60
MgO	2.30	2.67	1.84	1.98	4.01
ZnO	10.74	6.98	4.98	4.06	7.84
P	0.37				
Fe	23.25	21.74	23.69	25.30	21.74
Mn	13.82	12.56	12.13	14.64	16.29

[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 338.

The following are average analyses of the old clinker from different furnaces:

Average analyses of clinker from the zinc oxide furnaces.[a]

	Passaic Zinc Company.	New Jersey and Passaic Zinc companies.		Lehigh Zinc and Iron Company.		
SiO_2	18.56	20.14	18.43	25.16	27.66	25.13
Fe_2O_3	36.21	31.37	30.13	28.99	35.77	33.24
MnO	15.69	15.96	13.18	9.45	13.46	13.47
ZnO	4.70	3.76	4.43	4.55	5.93	5.63
Al_2O_3	4.07	4.44	8.65	6.57		
CaO	16.70	15.61	14.67	12.80		
MgO	1.92	2.59	3.20	4.55		
Unburnt coal	1.85					
P				.036		
Fe	25.35			20.29		
Mn	12.37			7.32		

[a] Weeks, J. D., Mineral Resources U. S. for 1885, pp. 339-340; also Eleventh Census U. S., Mineral Industries, p. 328.

The following analyses show the composition of spiegeleisen produced by the New Jersey Zinc Company from the old clinker:

Analyses of spiegeleisen produced by New Jersey Zinc Company.

Mn	11.586	11.67
Fe	83.250	83.23
Si	.367	.99
P	.196	.19
C	4.632	4.02
	100.031	100.10

JAMES RIVER-STAUNTON RIVER REGION.

GEOGRAPHY AND GEOLOGY.

The manganese-bearing area of the Piedmont region of Virginia lies northeast and southwest of Lynchburg. It extends from the southern end of Albemarle County southwestward along James River and passes through Mount Athos, Evington, and Lynch to Pittsville, its total length being about 75 miles. (See Pl. II.)

The country rock is decomposed mica schist interlayered with partially decomposed granite. Although this material is largely sand and clay, it retains the original textures to a remarkable degree. It is generally reddish in appearance, though frequently gray and brown colors prevail.

OCCURRENCE OF THE ORES.

The ore commonly occurs as nodules in layers of micaceous brown and yellowish-brown clay, at or near the contact of decomposed mica schist with granite. Such clay layers vary in width from a few inches to 20 feet or more, grading on both sides into the rocks bounding it.

Most of the ore is in the form of kidneys or large nodular masses embedded in the clay, some masses weighing as much as 600 pounds having been taken from the mines. These often contain cavities, lenses of white quartz, or partly replaced fragments of rock. The ore is mainly dark-blue or steel-gray granular pyrolusite, but crystalline pyrolusite and amorphous psilomelane occur with the granular ore.

The ore-bearing clay is very similar to the mica schist residuum forming the wall, though generally of different color, and grades into it imperceptibly, the ore masses becoming less abundant with increase of distance from the contact and finally disappearing. The granite near the ore-bearing layer is partly replaced by granular pyrolusite. At some places considerable masses are entirely replaced; at others, irregular specks of ore are scattered through the granite; the nearer the ore body the more thorough is the replacement. This partly replaced zone is generally several feet in thickness. Crystalline limestone has been found associated with the ore deposits, but its relation to the ores is not known.

The quantity of ore in the ore-bearing clay layer varies greatly. In some places 80 to 90 per cent may be ore, and 50 feet distant along the strike more than half the material may be clay. The same conditions prevail across the layer and with depth.

Besides the large masses of manganese ore, there occur in some of the mines, in association with these, small buttons of ore and small seams and irregular replacements in residual clay. In some of the mines a black manganiferous earth, locally known as "umber," is associated with the ore-bearing clays. This occurs in compact masses, but is soft and brittle and contains an abundance of mica flakes. The original nature of the umber is not known, but it is thought by some[a] that it may be residual from crystalline limestone layers.

There are a large number of old mines and workings in the James River and Staunton River valleys, but only one mine is now operating, namely, that of the Piedmont Manganese Company, southeast of Lynchburg. Among the better known of the mines are the Cabell, Bugley, and Piedmont mines, near Warminster, Nelson County; the Belmont or Simpson mine, in Nelson County, near Midway Mills; the Davis mine, in Nelson County; the Leets mine, near Mount Athos, Campbell County; the Saunders property, near Evington, Campbell County; the Theresa mine, near Otter River, Campbell County, and the Bishop mine, near Lynch, Campbell County. Besides these, small manganese prospects occur at other localities in Campbell, Nelson, and Appomattox counties.

Manganiferous iron ores occur at Pittsville, Pittsylvania County, and in Amherst County.

DESCRIPTIONS OF MINES AND DEPOSITS.

Piedmont Manganese Company's mine.—The Piedmont Manganese Company's mine is east of Little Beaver Creek, in Campbell County, about 2 miles southeast of Mount Athos. The workings are on the east and west slopes of a small ridge and consist of several old tunnels near the eastern base and a recent shaft near the summit. The shaft has drifts at the 80-foot and 105-foot levels, the latter just begun. The ores occur in a brown micaceous clay bed which has a general northeast-southwest strike and dips steeply to the southeast. This layer is between a decomposed granite on the hanging wall and a residual micaceous clay on the foot wall. It runs diagonally through the hill on which the mine is situated, and may be traced for a quarter of a mile to the northeast. Masses of "umber" are found here and there along it. The main ore-bearing layer as exposed on the 80-foot level is about 50 feet southeast of the shaft. It varies in thickness from a few feet to 10 feet or more, but it grades into the formations on either side, and small quantities of ore occur in both hanging and foot walls. (See fig. 2.) Later development not seen by the writer has shown the ore to extend for a distance of 20 or 25 feet on either side of the main layer at the widest part and to continue along the strike for 100 to 150 feet.

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[a] Watson, Thomas L., personal communication.

The ore occurs in kidneys or large masses and is mainly in the form of granular pyrolusite, either massive or with concentric structure. Crystalline pyrolusite and amorphous steel-blue psilomelane are associated with it, but are much less abundant. Lenses of quartz, fragments of unaltered rock, and cavities lined with botryoidal surfaces likewise occur in the ore masses. The ore locally may compose 85 or 90 per cent of the ore-bearing layer, forming a nearly solid body with interstices filled with clay, while elsewhere more than half the layer may be clay in which the ore is embedded in lumps. The micaceous clay foot wall is light brown, dark brown, or gray, by layers, and is residual from mica schist. The layers and schistosity have the same strike and dip as the ore-bearing layer. The foot-wall clay is similar to the clay associated with the ore and grades imperceptibly into it.

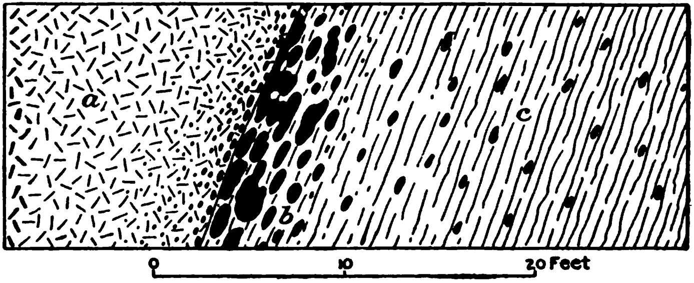

FIGURE 2.—Sketch showing the occurrence of manganese ore at the Piedmont Manganese Company's mine. *a*, Granite (containing ore); *b*, manganese ore; *c*, decomposed mica schist (containing ore).

There is a well-defined contact between the ore-bearing clay and the decomposed hanging-wall granite, although the ore itself is not confined by this contact. For some distance from the contact the granite contains specks and irregular patches of pyrolusite, which stain and partly replace it. The specks nearest the contact are larger and more numerous and in some places compose more than half of the mass of the rock.

The relation of the "umber" to the ore is not definitely known, but where it occurs in this mine it forms part of the hanging wall.

The ore is washed and dried and ground in a mill near the mine, and the powder is shipped away in barrels. It is used mostly for chemical work and coloring fancy brick.

The following is an analysis of ore from the Piedmont Manganese Company's mine:

Analysis of manganese ore from the Piedmont Manganese Company's mine.[a]

Mn	55.65
Fe	2.45
SiO_2	.93
Al_2O_3	.18
CaO	.81
MgO	.22
P	.341
MnO_2	84

Leets mine.—The Leets mine is in Campbell County, about 1 mile east of Mount Athos. The workings are underground and are now inaccessible, but in a surface cut the probable occurrence of the ores is shown. In this cut there is a vertical layer of brown micaceous clay between decomposed granite, with a few layers of micaceous clay, and alternating layers of various-colored micaceous clays. The ore occurs in seams at the contact of the granite and the brown micaceous clay layer, and in specks in the granite adjacent. Judging from analogy with other mines, the ore underground is probably distributed through the brown micaceous clay layer. The ore mined consisted of kidneys and large masses, mainly of granular pyrolusite, associated with smaller amounts of crystalline pyrolusite and of psilomelane. The following are analyses of ore from the Leets mine:

Analyses of manganese ore from the Leets mine.[a]

Mn	43.58	45.87	44.18
Fe	5.24	5.34	6.64
P	.316	.257	.274
SiO_2	7.15	7.77	7.73

[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 311.

Saunders property.—The Saunders property is in Campbell County, about 2 miles east of Evington. The country rock consists of alternating layers of red, yellow, and gray sand and clay, residual from schist and granite, having a general northeast-southwest strike and a dip of 50° to 75° southeast. Manganese ore occurs locally in several of these layers for a distance of about a quarter of a mile along the strike. In places the ore is in the form of soft, black seams, or of small, irregular nodules of psilomelane, an inch or two in diameter, while elsewhere large kidneys of granular pyrolusite, 5 or 6 inches in diameter, are found. The ore is scattered and the deposits are small. The Saunders property has been a recent producer, but not long ago operations were suspended.

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[a] Pennsylvania Steel Company, analysts. Kindly furnished by Mr. D. W. Myers, president Piedmont Manganese Company, Lynchburg, Va.

Piedmont mine.—The Piedmont mine is in Nelson County, about 2 miles north by west of Warminster. It has not been worked for many years and the former shaft is completely fallen in. The relation of ore to country rock, however, may be seen near the surface. The deposit here also, as in the mines described above, has a northeast-southwest strike and dips to the southeast. Decomposed granite forms the hanging wall. Near the contact with the ore it contains specks, patches, and bands of manganese oxide as fillings and replacements. Below the granite is the main deposit of ore, consisting of pyrolusite and psilomelane in brown micaceous clay. The ore and clay are intimately intermixed, but the former is predominant. Below the main deposit psilomelane occurs as small buttons scattered through hard, micaceous clay of the same nature as that above.

Cabell mine.—The Cabell mine is in Nelson County, about a quarter of a mile southwest of the Piedmont mine. The workings are very old and consist of a large, irregular pit and several shafts. Manganese ore, red residual clay, and grayish-white quartz-mica sand are exposed at several places on the walls of the pit, but their relations could not be determined. The main deposit of ore is a fairly solid mass of lumps and bands, associated with reddish residual clay.

The following are analyses of ore from the Cabell mine:

Analyses of manganese ore from the Cabell mine.

	1.	2.	3.
MnO_2	65.20	....	....
MnO	4.75	....	....
Fe_2O_3	6.20	....	....
Al_2O_3	3.93	....	....
CaO	1.43	....	....
MgO	.41	....	....
H_2O	3.02	....	....
P_2O_5	.42	....	....
SO_2	.30	....	....
SiO_2	14.20	....	....
	99.86	....	....
Mn	44.87	44.30	43.02
Fe	4.34	3.67	4.24
P	.18	.243	.182
Si	....	17.45	18.51

1. Am. Chemist, August, 1871, p. 50.
2, 3. Weeks, J. D., Mineral Resources U. S. for 1885, p. 312.

Other mines.—The Davis mine in Nelson County was operated during the eighties. The following is an analysis of a picked sample of the manganese ore mined:

Analysis of manganese ore from the Davis mine.[a]

MnO_2	90.42
Fe_2O_3	2.24
Al_2O_3	1.13
CaO	1.22
MgO	2.28

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[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 312.

SiO_2	1.12
P_2O_5	.43
H_2O	1.25
Mn	57.16
Fe	1.56
P	.19

A deposit of manganiferous iron ore occurs at Pittsville,[a] Pittsylvania County. The ore has the following composition:

Analyses of manganiferous iron ore from Pittsville.

Mn	24.78	27.86
Fe	29.86	28.14
P	.362	.247
SiO_2	7.02	4.32

At Stapleton Mills and Walkers Ford station, in Amherst County,[a] manganiferous iron ore has also been found. The ore from the former locality has the following composition:

Analysis of manganiferous iron ore from Stapleton Mills.

MnO	54.669
Mn	34.56
Fe	22.57
P	.08

MINOR DEPOSITS.

NEW JERSEY.

A small deposit of manganese ore was found in Triassic rocks near Clinton,[b] Hunterdon County, N. J. The ores consist partly of pyrolusite and partly of braunite and have the following composition:

Mn	47
Fe_2O_3	7
Insoluble	25

PENNSYLVANIA.

Oxides and carbonate of manganese, as well as silicates, such as manganiferous garnets, occur in the crystalline area of Pennsylvania. They have been found in the gneissic rocks on Pennypack Creek near Bustleton,[c] Philadelphia County, and near West Chester,[c] Chester County.

MARYLAND.

In the Maryland crystalline area manganese ores have been found in small quantities at Brookeville[d] and Mechanicsville,[e] Montgomery County, and at New Market, Frederick County.

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[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 311.

[b] Idem, p. 336.

[c] Carpenter, G. W., Am. Jour. Sci., 1st ser., vol. 14, 1828, pp. 4, 12.

[d] Penrose, R. A. F., jr., Manganese: Its uses, ores, and deposits: Ann. Rept. Arkansas Geol. Survey for 1890, vol. 1, p. 401.

[e] Ducatel, J. T., and Alexander, J. H., Am. Jour. Sci., 1st ser., vol. 27, 1835, pp. 20, 25.

NORTH CAROLINA AND SOUTH CAROLINA.

Ores of manganese, in the form of silicates and of oxides, are found in the crystalline and metamorphic rocks of the Piedmont region of North Carolina and South Carolina. The best-known deposits are associated with a narrow belt of schists that crosses the boundary between North Carolina and South Carolina in a northeast-southwest direction, passing a short distance east of the towns of Blacksburg, S. C., and Kings Mountain, N. C. This belt extends northeastward into Lincoln and Catawba counties, N. C., and southwestward beyond Glenn Springs, Spartanburg County, S. C.[a]

From North Carolina manganese ore has been reported,[b] also from localities west of Lenoir, Caldwell County, and north of Dobson, Surry County, and from Cabarras and Stokes counties. The deposits in Surry County consist of manganiferous garnet.[c] Manganiferous iron ore occurs at the Buckhorn iron mine, Chatham County.

In South Carolina other manganese deposits occur in a belt extending from New Market, Greenwood County, southward to McCormick, Abbeville County. Wad or bog manganese occurs in the northeastern part of Chester County, 4 miles southeast of Catawba Junction,[b] and ores are also reported from Greeneville,[d] Greeneville County.

The manganese deposits of the Blacksburg–Kings Mountain area consist of silicates superficially altered to black oxide. The manganese-bearing formation[c] consists largely of dark schists with some conglomerate beds. It occupies a belt which varies in width from a half mile to less than a mile, but may be traced for long distances in a northeast and southwest direction along the strike. In general the conglomerate beds form the outer boundaries of the belt, but locally they are interstratified with schists. All the beds have a nearly vertical dip and a general northeast-southwest strike. The schist-conglomerate series is bounded on the southeast by a belt of metamorphosed volcanic tuffs and on the northwest by a belt of chloritic and hornblende schists and biotite granite.

The manganese ores occur in the form of psilomelane and pyrolusite along the outcrop of the dark schist belt, appearing as black stains and in small particles along cracks. The area stained by manganese oxide is in some places 200 or 300 yards wide, but ore occurs only in a small portion of this area, appearing as small veins and probably as replacements along fractures. Near Blacksburg the manganese stains occur along two leads[e] running northeastward for about 5 miles to a point where they join and continue as one. At points along this extent one lead measured 7 or 8 feet and the other 25 feet in width. At the surface the manganese is largely present as a stain, but with depth the rocks become richer in manganese oxide and small streaks of ore occur, until at a depth of about 25 feet solid crystalline ore, with a matrix of shale and quartzite and a foot wall of hard yellow shale, is said to have been reached.

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[a] Sloan, Earle, Mineral localities of South Carolina: Bull. South Carolina Geol. Survey, ser. 4, No. 2, p. 95.

[b] Penrose, R. A. F., jr., op. cit., p. 413.

[c] Sterrett, D. B., personal communication.

[d] Sloan, Earle, op. cit., p. 98.

[e] Weeks, J. D., Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, p. 200 (H. B. C. Nitze quoted).

In North Carolina the principal locality where manganese occurs in this belt is in the southern part of Gaston County, about 1 mile southeast of Kings Creek. The following are analyses of manganese ore from the black schist belt:

Analyses of manganese ores from the black-schist belt.

	1.	2.	3.	4.	5.	6.	7.	8.
MnO							14.11	23.13
MnO_2							6.71	1.85
Mn_3O_4	29.78							
Fe_2O_3	12.146						13.88	11.06
FeS	.218							
SiO_2	40.395	2.92	7.37	4.66	1.00	2.45	43.94	45.70
Al_2O_3	9.025						14.72	13.42
CaO				3.50				
P_2O_5	.030							
SO_3	.024							
Mn	21.45	57.353	53.16	51.15	60.38	57.83	15.17	19.09
Fe	8.602	1.435	1.98	2.00	.67	.78	9.71	7.74
P	.013	.050	.050	.055	.029	.032	.06	.04
S	.011						.06	Trace.
Ti							Trace.	.43

1. Kings Mountain, N. C. Weeks, J. D., Eleventh Census U. S., Mineral industries, p. 305.
2, 3, 4, 5, 6. Blacksburg, S. C. Weeks, J. D., Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, p. 201.
7. Smith Mountain, near Cherokee Ford, Cherokee Creek, S. C. Sloan, Earle, loc. cit.
8. Wofford property, 8 miles south of Glenn Springs, Spartanburg County, S. C. Sloan, Earle, loc. cit.

In Chatham County,[a] N. C., sheets of laminated black oxide of manganese 1 to 2 inches thick occur with iron ore at the Buckhorn iron mine. The iron ore in the lower part of the deposit is manganiferous, the manganese occurring as silicate. The following is an analysis of the lower ore:

Analysis of manganiferous iron ore from the Buckhorn mine.

MnO	22.80
Fe	18.41
P	.02
SiO_2	30.50
Al_2O_3	19.20

The manganese belt between New Market, Greenwood County, and McCormick, Abbeville County, S. C., contains several deposits of ore of rich quality,[b] associated with mica and sericite schists. The best known of these are about 1 mile southwest and one-half mile north of

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[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 344.

[b] Sloan, Earle, op. cit., p. 95.

McCormick, Abbeville County, 2 miles west of Breezewood and 5 miles south of Greenwood, Greenwood County.

The deposit north of McCormick consists of nodular concretions of psilomelane and pyrolusite embedded in soft brown earth consisting of hydromica and manganese oxide particles, in a zone about 7 feet wide at the base of a soft gray mica schist formation, striking N. 72° E. and dipping 70° NW. The foot wall of this zone consists of hard red mica schist. Manganese may be traced for a distance of a thousand feet along the strike in a belt of varying width. Locally hard siliceous ore occurs in a solid body with numerous veins of white quartz.

West of Breezewood, Greenwood County, the manganese ore occurs in a vein 5 to 6 feet wide in mica slates.

The following are analyses of manganese ore from the New Market–McCormick area:

Analyses of manganese ore from the New Market–McCormick area.

	1.	2.	3.	4.	5.
MnO	3.73	....	10.66	15.68	18.54
MnO_2	75.28	....	71.56	31.78	39.77
Fe_2O_3	14.56	....	2.07	6.22	4.63
SiO_2	3.54	8.10	2.59	15.70	12.63
Al_2O_3	2.63	....	....	....	....
P_2O_5	.24	....	....	....	....
H_2O	....	9.00	....	....	....
Mn	....	45.018	53.50	32.24	39.50
Fe	....	2.75	1.45	4.35	3.24
P	....	.085	.24	.03	.07
S	.02	....	.04	Trace.	Trace.
Ti	....	....	Trace.	Trace.	Trace.

1, 2. Dorn lands, McCormick, Abbeville County, S. C. Weeks, J. D., Eleventh Census U. S., Mineral industries, p. 307.
3. Hard nodular ore, one-half mile north of McCormick, Abbeville County, S. C. Sloan, Earle, Mineral localities of South Carolina: Bull. South Carolina Geol. Survey, ser. 4, No. 2, p. 97.
4. Soft ore forming the matrix for the preceding. Same locality as above. Sloan, Earle, loc. cit.
5. Burnet property, 2 miles west of Breezewood, Greenwood Creek, S. C. Sloan, Earle, loc. cit.

GEORGIA.[a]

In the crystalline area of Georgia there are a number of small deposits of manganese ore, but none of commercial importance have been found. In Lumpkin County manganese oxide occurs in small seams along planes of schistosity or fracture in residual clays of hornblende, chlorite, mica, and quartz schists. Botryoidal masses of very pure oxide have been found locally.

Near Mount Airy, Habersham County, there are several localities where manganese oxides occur in small quantities. The prevailing rock in this area is mica schist, in places very quartzose, cut by dikes of basic eruptives and by quartz veins. About 2 miles northeast of Mount Airy manganese oxide occurs as cement in a brecciated quartz vein 3 feet wide, cutting mica schist. It is also found as seams along schistose planes and as cement between quartz grains in residual clay and sand from the mica schist.

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[a] Watson, T. L., Preliminary report on the manganese deposits of Georgia: Bull. Georgia Geol. Survey No. 14, pp. 168-177, 182-199.

The following is an analysis of the ore:

Analysis of manganese ore from Mount Airy.[a]

Mn	54.16
Fe	1.32
SiO_2	3.73
P	.092

Near Currahee Mountain, 6 miles southwest of Toccoa, Habersham County, small fragments of manganese and iron oxides and seams and stains of manganese occur in residual clays of mica schist.

Manganese ores occur in Hart and Franklin counties, near Bowersville, as stains and fragments in residual clays from mica schist. On the Brown property, 1½ miles east of Bowersville, massive blue or steel-gray manganese oxide occurs in red residual clay as large masses, the largest several yards in diameter. These masses are generally porous or cellular and contain a large amount of silica in the form of quartz grains. Small pellets of soft ore also occur. The ores appear to have been derived from the mica and to have become concentrated between the quartz grains on the decay of the latter.

Manganese ore is found in Haralson and Paulding counties, several miles north of Draketown. It occurs in masses along the contact of a banded quartzite and a decomposed mica schist, and not in the nodular form so common elsewhere. The quartzite carries numerous grains and crystals of magnetite. The manganese ore is either amorphous or crystalline and generally contains considerable magnetite and some hematite and limonite, forming a manganiferous iron ore. Many of the ore masses occur through the banded quartzite layer rather than at its contact with the residual clays. At a number of places the mica schist is garnetiferous, the garnets being altered in the residual clay to iron and manganese oxides.

In Paulding County, 4½ miles east of Draketown, nodular blue pyrolusite occurs, embedded in residual clays of a garnetiferous mica schist.

ORIGIN OF THE MANGANESE ORES OF THE PIEDMONT REGION.

The crystalline rocks of the Piedmont region contain an abundance of manganese-bearing minerals, such as amphiboles, pyroxenes, garnets, and micas. The manganese is present in these largely in the form of protoxide, which on the decomposition of the minerals becomes converted into peroxide, forming pyrolusite when pure and psilomelane or wad when it contains an admixture of other oxides and foreign constituents. Frequently the minerals are altered in place and the manganese and iron oxides and other residual products resulting from the decomposition remain as specks in the residual sand and clay. In some places they are concentrated in nodular masses or in seams along joints or planes of schistosity. Silica seems to have considerable affinity for manganese oxides, which in many places form cementing material between sand grains. Workable deposits are formed where the seams, nodules, or irregular masses of manganese oxide are gathered into pockets or along layers. This concentration takes place through the medium of circulating meteoric waters, the manganese being taken into solution on the decomposition of the manganese-bearing minerals and deposited where conditions are favorable. Layers of crystalline limestone or of quartzite, brecciated quartz veins, fault or joint planes, masses of sandy material, or previous deposits of manganese minerals may constitute favorable places or conditions for the deposition of manganese.

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[a] Watson, Thomas L., op. cit., p. 171.

COMMERCIAL IMPORTANCE OF THE ORES.

The ore associated with the granites and schists of the Piedmont region is very pure and of high grade. It is largely granular and crystalline pyrolusite, valuable as an oxidizer and as a coloring material. The principal deposits are those in the James River and Staunton River valleys in Virginia and those near McCormick, in southern South Carolina, at both of which localities a small quantity of ore has been recently mined. The deposits of the Kings Mountain belt, in northern South Carolina, while occupying a considerable area, are mostly in the form of small veins and replacements, few of which are of sufficient extent to be mined. No ore has been shipped from this region. All the other deposits mentioned are unimportant.

Manganese ore has been produced in the James River valley for many years, and a large number of pockets there have been mined and abandoned. They were found to be of small extent, and after a number of years of steady mining became exhausted. Most of the deposits consisted of a group of pockets, each of which was mined in turn. Only one deposit, that of the Piedmont Manganese Company, is being mined at present, and this promises to be more continuous than the deposits previously mined. Ore of high grade is produced and is ground at the mine for use as coloring material.

In South Carolina the McCormick deposit has been mined recently, the ore being used in the manufacture of spiegeleisen and ferromanganese. South Carolina has not been an important producer.

APPALACHIAN REGION.

GENERAL STATEMENT.

The Appalachian region is the southern continuation of the western New England sedimentary area and extends from Pennsylvania through Virginia and Tennessee into Georgia and Alabama, including a small part of western North Carolina. This belt is bounded on the east and southeast by the Piedmont region and on the west by the Cumberland and Allegheny plateaus. In Pennsylvania and Maryland the Appalachian belt includes a number of parallel mountain ranges and valleys. In Virginia and in the area farther south its eastern portion is occupied by a broad valley with minor ridges, while the western part consists of a number of parallel ridges and valleys. In Virginia the Appalachian Valley is bounded on the east by the Blue Ridge; in Tennessee and North Carolina its eastern boundary is formed by the broad mountain belt between the Unaka Mountains on the west and the Blue Ridge on the east. The rocks of the Appalachian region are of Paleozoic age. They extend eastward to the Blue Ridge, forming its western slope in Virginia, while farther south, where the mountain belt broadens, they form the Unakas and several interior ranges east of them.

Manganese ores occur at intervals throughout the Paleozoic rocks from Pennsylvania to Alabama. The principal deposits lie in a narrow belt along the extreme eastern edge of the Appalachian Valley. It includes the chief Pennsylvania deposits, and in Virginia is represented by the deposits at the western foot of the Blue Ridge and by those of the New River district south of Pulaski, Wytheville, and Marion. In Tennessee the deposits in Shady Valley, near Unicoi, in the vicinity of Newport and Del Rio, and in the Chilhowee Mountains belong in this belt; and farther south Cherokee County, N. C., Blue Ridge, Cohutta Springs, and the Cartersville region in Georgia, and Cleburne County, Ala., are included in it. Other deposits occur inside the Appalachian Valley, in a second belt a little west of and parallel with the main belt. This is represented in Virginia and West Virginia by the deposits near Cedar Creek, Woodstock, Gale, Glenmore, and Goshen and by others farther southwest, which are undeveloped. In Tennessee a deposit is found near Sweetwater and others are reported from Morristown and points farther northwest. In Georgia the deposits of Tunnel Hill, Lindale, Barnsley, and the Cave Springs district are in this belt, and continuations of it are. found in Alabama, ores being reported from Cherokee County, Ala., and other localities.

Closely associated with the manganese deposits and coextensive with them there are numerous deposits of limonite.

The manganese deposits of the Appalachian region occur in residual clay and sand derived from Cambrian, Ordovician, and, to a slight extent, from Silurian sediments. With the residual clays there are associated in many localities later fluviatile clays of Tertiary or Cretaceous age. The Appalachian Mountains, represented by the Blue Ridge in the north and by the broad mountain belt between the Unaka Mountains and the Blue Ridge in the south, are on the contact between the crystallines of the Piedmont region and the Paleozoic sediments to the west. Near the contact the sediments dip in general to the west and northwest and have a general northeast-southwest strike, but in the valley there has been much folding and faulting, making the dips irregular, though the general strike of the beds remains the same. On going westward from the mountains one therefore crosses successively higher geologic horizons. The principal ore deposits—that is, those of the eastern belt—are in the area underlain by Cambrian shale, quartzite, and limestone; those in the western belt are underlain in Tennessee and Georgia by the Cambro-Ordovician Knox dolomite and in Virginia by Silurian rocks.

In the Appalachian region, besides the deposits of manganese ore, there are numerous manganiferous iron ore deposits—in fact all gradations may be seen from pure manganese to pure iron ore deposits. Most of the manganese-ore deposits contain some iron ore, and, on the other hand, many of the iron-ore deposits contain small quantities of manganese ore. The term manganiferous iron ore is applied to those ores that contain a notable amount of both constituents, and such deposits occur at many places, especially in the eastern belt.

BLUE RIDGE REGION.

GEOGRAPHY AND TOPOGRAPHY.

The principal deposits of the valley of Virginia are situated at the western foot of the Blue Ridge at intervals between Front Royal on the north and Roanoke on the south. (See Pl. II.) The following is a list of the locations of the principal mines and prospects, from north to south. Of these only the Happy Creek, Dry Run, Crimora, Lyndhurst, and Vesuvius mines have recently produced ore.

Manganese deposits of Blue Ridge region.

Front Royal	Happy Creek mine.
Compton	Dry Run mine.
Kimball	Fronk property.
Stanleyton	Eureka Manganese mine (Round Head tract).
Shenandoah	Kimball mine.
	Watson bank.
	Garrison bank.
Elkton	Kendall and Flick mine.
Islandford	Seller mine.
	Big Run mine.
	Shaver bank.
Crimora	Crimora mine.
	Old Dominion mine.
Dooms	Watt property.

Lyndhurst and Sherando	Lyndhurst mine.
	Mount Torry tract.
Stuarts Draft	Kennedy tract.
Vesuvius	Vesuvius mine (Fauber bank).
	Mine bank.
	Blue bank.
	Kelly bank.
Midvale	Midvale mine.
Lithia	Gowens bank.
	White bank.
	Deal bank.
Troutville	Houston banks.
	Stoner mine.

The mines are all east of the Norfolk and Western Railway, either at or very near the foot of the Blue Ridge. The same area contains the Blue Ridge iron-ore mines, but these are not confined so closely to the foot of the ridge, some of them being several miles up in the mountains and some a half mile out from the foot.

The Blue Ridge runs in a northeast-southwest direction and varies in width from 5 to about 15 miles. To the east of it is the Piedmont Plateau; to the west the valley of Virginia. The crest line has a general elevation from 2,500 to 4,000 feet, its highest point being Mount Pleasant, opposite Midvale, which reaches an elevation of 4,098 feet. The Blue Ridge consists of a central backbone with short transverse ridges extending out from it on either side between stream valleys. At the foot of these ridges on the west there is a gently sloping shelf which merges westward into the broad valley of Virginia. Most of the manganese deposits are on this shelf near the foot of the ridges. The valley of Virginia contains a large number of minor northeast-southwest ridges which divide it into smaller valleys. The valley immediately west of the Blue Ridge is drained southward by South River, a branch of the James, and northward by the South Fork of Shenandoah River. The headwaters of these streams rise at Lofton, a few miles north of Vesuvius.

GEOLOGY.

The Blue Ridge is on the contact between the ancient crystalline and metamorphic rocks of the Piedmont region and the Paleozoic rocks of the valley of Virginia and the region farther west. The following tables give the general succession of rocks for the northern and middle portions of the valley of Virginia:[a]

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[a] Bassler, R. S., Cement materials of western Virginia: Econ. Geology, vol. 3, No. 6, p. 510.

Campbell, H. D., The Cambro-Ordovician limestones of the middle portion of the valley of Virginia: Am. Jour. Sci., 4th ser., vol. 20, p. 445.

Keith, Arthur, Harper's Ferry folio (No. 10), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

Darton, N. H., Staunton folio (No. 14), Franklin folio (No. 32), and Monterey folio (No. 61), Geol. Atlas U. S., U. S. Geol. Survey.

General succession of rocks for the northern valley of Virginia.

- Devonian:
  - Jennings formation.
  - Romney shale. (Black shale.)
- Silurian:
  - "Monterey" (Oriskany) sandstone.
  - Lewistown limestone. (Carries Oriskany brown ore and manganese ore.)
  - Clinton (Rockwood) formation.
  - Cacapon sandstone.
  - Tuscarora quartzite.
- Ordovician:
  - Juniata sandstone.
  - Martinsburg shale.
  - Shenandoah group—
    - Chambersburg limestone.
    - Stones River limestone.
- Cambro-Ordovician:
  - Undifferentiated Shenandoah.
  - Sequence broken. (Brown ore and manganese ore.)
- Cambrian:
  - Antietam sandstone.
  - Harpers shale.
  - Weverton sandstone.
  - Loudoun formation.
- Algonkian:
  - Catoctin schist and granite.

General succession of rocks for the middle valley of Virginia.

- Devonian:
  - Jennings formation.
  - Romney shale. (Black shale.)
- Silurian:
  - "Monterey" (Oriskany) sandstone.
  - Lewistown limestone—
    - Pure heavy-bedded limestone. (Carries Oriskany brown ore and manganese ore.)
    - Cherty limstone.
    - Limestone and sandstone.
  - Clinton (Rockwood) formation –
    - White quartzite.
    - Purple and gray shale. (Carries fossil hematite.)
    - Red sandstone.
- Ordovician-Silurian:
  - Massanutten sandstone.
- Ordovician:
  - Martinsburg shale.
  - Liberty Hall limestone.
  - Murat limestone.
- Cambro-Ordovician:
  - Natural Bridge limestone. (Carries "valley" brown ore.) } Shenandoah group.
- Cambrian:
  - "Buena Vista" shale.
  - Sherwood limestone.
  - Lower Cambrian quartzite. (Carries "mountain" brown ore and manganese ore.)
  - Lower Cambrian shales and quartzites. (Carries specular hematite.)
- Pre-Cambrian:
  - Crystalline and metamorphic rocks.

The crystalline rocks are mostly granite, gneiss, and schist, very much metamorphosed and containing numerous intrusives. They compose the eastern portion of the Blue Ridge and form the basement upon which the later sediments have been deposited. They contain no manganese ores in this district.

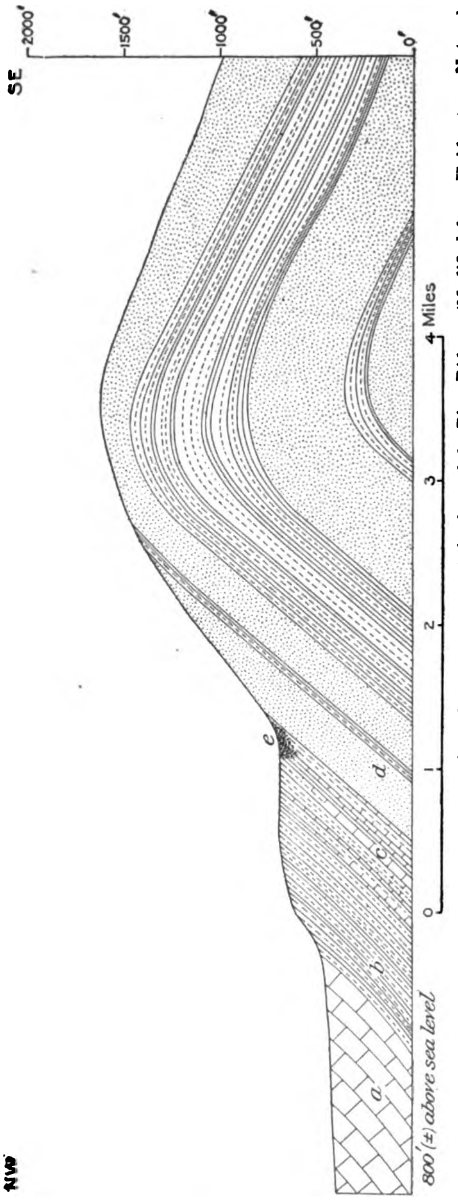

FIGURE 3.—Sketch showing the occurrence of a pocket of manganese ore at the foot of the Blue Ridge. (Modified from Holden.) *a*, Natural Bridge limestone; *b*, "Buena Vista" shale; *c*, Sherwood limestone (with interbedded shale); *d*, Cambrian quartzite; *e*, pocket of manganese ore.

The Cambrian formations consist in general of lower quartzites and shales. Above these is a heavy quartzite bed, which is the surface rock in the western portion of the Blue Ridge, and above this is the Sherwood limestone with the overlying "Buena Vista" shale, which forms the gently sloping bench at its western foot. On this bench occur the manganese deposits and most of the Blue Ridge limonite deposits. (See fig. 3.) The "Buena Vista" shale and Sherwood limestone have been removed from the top and slopes of the Blue Ridge, leaving the quartzite as the surface rock. On the western slope, the dip of the rocks is in general steeply to the northwest, but becomes very irregular through the valley on account of folding and faulting. For a considerable extent along the west front of the Blue Ridge either or both the Sherwood limestone and "Buena Vista" shale are absent on account of faulting.

The Natural Bridge limestone forms most of the eastern portion of the valley, but overlying Ordovician, Silurian, and Devonian rocks occur locally in the valley ridges. The Natural Bridge limestone in general is bluish gray and crystalline, and locally contains an abundance of chert.

OCCURRENCE AND CHARACTER OF THE ORES.

GENERAL RELATIONS.

Manganese ores occur as scattered fragments in small quantities throughout the Blue Ridge belt, but only locally are they sufficiently concentrated to be of commercial value. As a rule these local concentrations consist of fragments gathered in irregular pockets in clay several hundred yards in area and generally not more than a few hundred feet deep, but in some places, as at Crimora, the ores have collected in clay in basins in the underlying bed rock and the deposits are of greater extent.

The clay in which the ores occur is derived largely from the decomposition of the lower Cambrian quartzite and the Sherwood limestone, though undoubtedly some of it was derived from the overlying shale. It is probable that small quantities of manganese ore also occur in the later fluviatile clays associated with the residual material. Usually the clay is stiff, though locally it is sandy. In color it varies from white through yellow, brown, and red to black, the different-colored varieties being generally intermixed. The black clays are colored by manganese and are often associated with manganese pockets. Frequently fragments of undecomposed rock, mostly sandstone or chert, are contained in the residual clay.

The deposits occur at or near the contact of the lower Cambrian quartzite with the overlying formations, both where faulting has taken place and where the rocks are in their normal succession.

FORMS OF THE ORES.

The ores occur in several different forms and associations, the principal forms being the following:

1. Blue or black psilomelane in kidney-shaped masses scattered through clay. Generally these are massive and structureless in the interior, but some of them show a concentric arrangement of layers.
2. Irregular bodies of psilomelane and pyrolusite, occurring in black manganiferous clay and to a smaller extent in other clays.
3. Breccia ore, composed of sandstone or chert fragments cemented by psilomelane or pyrolusite. This ore generally occurs in large masses rather than as small fragments scattered irregularly through clay.
4. Crystalline and granular pyrolusite with some psilomelane, occurring as cavity fillings, seams, and replacements in sandstone horses or in compact sandy clay.

(1) The ores of the first class are scattered through horizontal or slightly inclined layers or lenses of clay which are separated by areas of barren clay. (See fig. 6.) A number of such ore-bearing lenses grouped together constitute a deposit or pocket. The clay in which the ore occurs is orange, yellow, brown, or variegated, and generally contains fragments of sandstone which may have ores of classes 3 and 4 associated with them. The ore kidneys range in diameter from half an inch to 6 or 8 inches, but the larger ones are irregular and not of the typical nodular form. In general the kidney ore is massive, compact, and structureless, but some of the nodules show concentric layering, and in some of them cavities lined with black, sooty wad occur between the layers. Rarely the nodules include small crystals of pyrolusite. When taken from the mine the ore masses are covered with a thin coating of clay, generally yellow or brown, but in some deposits bright red, as at the Crimora mine. This coating is removed during the washing and the kidneys become black. Where the clay is markedly sandy the nodules contain grains of sand and small fragments of sandstone, thus grading toward breccia ore.

In some places the nodules are a foot or more apart; in others they are closely packed together and may even be connected into branching masses.

(2) Irregular areas of black manganiferous clay are associated with the variegated clays in most of the deposits. Scattered through this clay and probably representing local spots of greater concentration there are irregular bodies and seams of manganese ore. Less numerous bodies of a similar nature are embedded in variegated clay, in the manner of kidney ore, with which they frequently occur in the same bed. They vary in diameter from a few inches to a foot or more and in shape from thin seams to masses consisting of irregular, crooked, intersecting cylinders with numerous cavities between, after the nature of coral. The term stalactitic ore has been applied to such porous cellular masses.

Most of the ore of this class is psilomelane, though some of the cavities in it are lined with pyrolusite. Pyrolusite appears to be more abundant in the bodies that are embedded in manganiferous clay.

(3) The breccia ore is found in large masses, many of them 2 or 3 feet in diameter. It consists of small fragments of sandstone or chert cemented together by psilomelane or pyrolusite, the former being predominant. A breccia ore mass may contain either of these minerals, exclusive of the other, but more commonly the two occur together in successive layers. Breccia masses are generally embedded in clay, but one deposit was found in solid quartzite. The percentage of the volume of the ore made up of the fragments as compared to that formed by the cementing material is variable, though as a rule the fragments make up less than one-half of the total mass. The

size of the fragments also varies; they range from mere grains of sand to masses 6 inches or more in diameter. Many breccia masses are covered with a thick coating of botryoidal ore in which few or no rock fragments occur.

(4) In many of the deposits, as at Crimora, there are residual masses of sandy clay, grading at some places into fairly compact sandstone; in others there are horses of sandstone below the clay, as in the Houston Banks. In these masses manganese ore, principally crystalline and granular pyrolusite, subordinately psilomelane, occurs as a replacement, as cavity fillings, and in veins. The replacement ore is generally psilomelane or granular and finely crystalline pyrolusite. In some places it occurs along vertical fissures; in others it replaces horizontal layers. Most commonly, however, it occurs irregularly on the border of the sandstone masses. The ores lining cavities and occurring in veins are associated with the replacement ores. Most of the veins are in the sandstone near the border of the replaced areas. The cavity fillings occur both in the replaced portions and in the sandstone. They consist of pyrolusite, often beautifully crystallized in coarse and fine needles. Wad frequently occurs as a coating of crystals in cavities.

DESCRIPTIONS OF MINES AND DEPOSITS.

Happy Creek mine.—The Happy Creek mine is in Warren County, about 2 miles east of Front Royal, at the base of one of the foothills of the Blue Ridge. It is primarily an iron-ore mine, but pockets of soft, granular pyrolusite occur locally in the limonite deposits, and occasionally a few carloads are shipped. The deposit is associated with a heavy quartzite bed in Cambrian shale.

Dry Run mine.—The Dry Run mine has been recently opened on an old manganese tract in Page County, about 1 mile south of Compton, by the Dry Run Mining and Development Company. The ore is largely psilomelane in botryoidal form, occurring as cement in a brecciated pocket in solid Cambrian quartzite. Quartzite fragments form the principal part of the deposit, the manganese ore seams between them varying in width, reaching in places a maximum of 4 inches. The ore contains numerous cavities lined with botryoidal forms.

Fronk property.—The Fronk property is in Page County, about 1 mile north of Kimball. Soft, dark-blue granular pyrolusite is found here in association with masses of brown iron ore. A shaft and several test pits have been sunk, but no ore has been shipped.

Eureka mine.—The Eureka manganese mine is on the northwest slope of Round Head Mountain, about 1½ miles southwest of Stanleyton, in Page County. A large amount of open pit work has been done and considerable manganese ore shipped. The ore is mainly psilomelane in porous masses up to a foot in diameter, scattered through red and yellow clay. Pyrolusite in needle-like crystals lines cavities in the psilomelane masses. Fragments of brown and purple quartzite are abundantly scattered through the clay.

The following analyses show the composition of this ore:

Analyses of manganese ore from Stanleyton, Va.[a]

	1.	2.
Mn	51.46	49.61
Fe	2.94	1.05
P	.23	.31
SiO_2	4.17	....
H_2O	4.97	....

[a] Watson, T. L., Manganese oxides: Mineral Resources of Virginia, p. 245.

Kimball mine.—The Kimball mine is an old manganiferous iron ore mine in Page County, on the west slope of Grindstone Mountain, about 3½ miles east of Shenandoah. The manganese ore is soft blue granular pyrolusite, embedded as pockets in variegated clay. Ore has been mined at two openings, known as the Atwood and the Bolan. The following are analyses of ore from this locality:[a]

Analyses of manganiferous iron ore from the Kimball mine.

	1.	2.
Fe	40.875	....
Fe_2O_3	....	70
Mn	7.349	....
MnO	....	13.31
SiO_2	15.44	4.73
Al_2O_3	....	.86
P	.084	Trace.
H_2O	....	11.02

Analysis 1 represents mixed ore (two-thirds Atwood and one-third Bolan).

Watson bank.—The Watson bank is on the west slope of Grindstone Mountain, about 1 mile south of the Kimball mine. It was being prospected during 1908.

Garrison bank.—The Garrison bank is an old manganiferous iron-ore mine on the lower west slope of Grindstone Mountain, about 1 mile northwest of the Watson bank. The manganese occurs as blue granular pyrolusite in pockets and seams in residual shaly and sandy clay. Ore of the following composition was reported in the early eighties from this mine:[a]

Analyses of manganese ore from the Garrison tract.

Mn	52.60	53.66
Fe	2.32	1.54
P	.32	.33
SiO_2	27.95	1.95

[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 314.

Kendall & Flick mine.—The Kendall & Flick mine is about 1 mile southeast of Elkton, Rockingham County. Several cuts, tunnels, and shafts have been opened at three localities, about one-fourth mile apart, on the west slope of a foothill of the Blue Ridge. The deposits consist of a mixture of manganese and iron ores embedded in variegated clay, either in separate pockets or mixed in the same mass. The manganese ore is largely psilomelane in cellular and nodular masses, with locally small scattered kidneys. Layers or lenses of dark-colored clay with wad are interbedded with the lighter-colored clays. The following are analyses of ore from the Kendall & Flick mine[a] and from other mines[b] near Elkton:

Analysis of manganese ore from the Kendall & Flick mine.

Mn	48.25
Fe	2.70
SiO_2	10.50
H_2O	4.00

Analyses of manganese ore from Elkton, Va.

Mn	43.94	49.66	48.75
Fe	3.43	8.53	2.79
P	.166	.076	.085
S	.07	.089	Trace.
SiO_2	15.88	1.80	15.08

Analysis of manganese ore from the Church Mountain mine, Elkton, Va.

Insoluble	22.11
Fe_2O_3 and Al_2O_3	5.14
Mn	39.20
Co	2.48
Ignition	11.30

Seller and Big Run mines and Shaver bank.—South of the Kendall & Flick mine, along the base of the Blue Ridge east of Islandford, between Elkton and Grottoes, there are several manganese and manganiferous iron-ore banks, among which the Seller mine, the Big Run mine, and the Shaver bank are the most important.

The ore at the Seller mine is blue psilomelane in kidneys and in porous, cellular masses embedded in sandy variegated clay. The kidneys vary in size from tiny particles to masses 8 or 10 inches in diameter, while the cellular ore occurs in large masses including areas of clay.

At the Big Run mine cellular psilomelane is found in large masses, some of them 4 or 5 feet in extent, embedded in dark brown and black clay. The black clay occurs in specks and irregular masses through the brown clay. Several deposits of brown iron ore are found near the manganese-ore deposits.

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[a] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, p. 431.

[b] Watson, T. L., Manganese oxides: Mineral Resources of Virginia., p. 251.

The Shaver bank is about half a mile south of the Big Run mine. Both iron and manganese ores are found here, the latter in the form of cellular psilomelane.

Crimora mine.—The Crimora mine is situated in Augusta County, 2 miles east of Crimora station, at the foot of the Blue Ridge. It is at present operated by Frank W. Wood, for Henry W. Poor & Co., of New York City. The deposit consists of manganese-ore masses of various sizes scattered through variegated clays in an elliptical basin in a canoe-shaped syncline of the Cambrian quartzite. The basin has a general north-south trend, and is about half a mile long, several hundred yards wide, and 200 feet deep. (See figs. 4 and 5.) It occupies a flat area bounded on the east and north by spurs of the Blue Ridge.

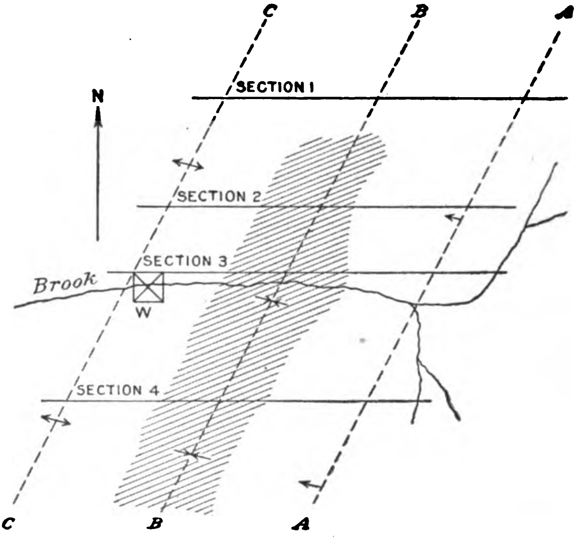
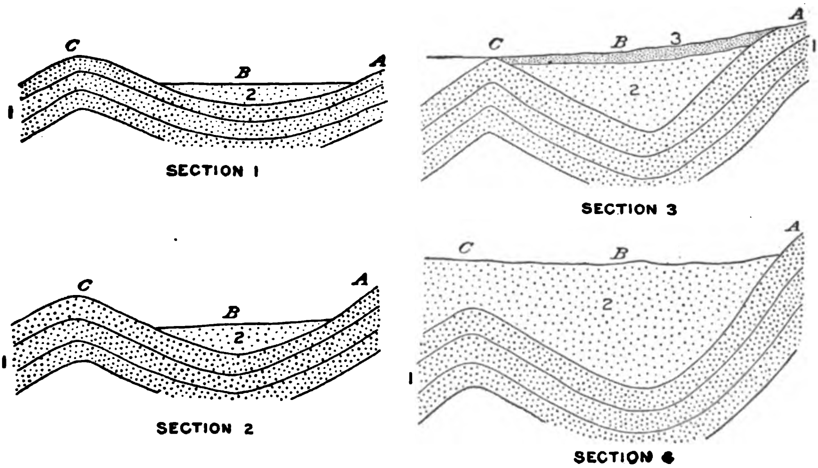


FIGURE 4.—Ground plan of the Crimora manganese deposit. (After Hall.) A-A, Eastern extent of syncline; B-B, axis of syncline; C-C, axis of anticline; W, location of washer. Shaded part shows manganese area. Scale, 1 inch = several hundred yards.

In the eighties and early nineties the Crimora mine consisted largely of underground workings. About 1895 these were abandoned and operations were begun for a system of hydraulic mining. A tunnel, over a mile long, was driven through the western rim of the quartzite basin into the lower portion of the deposit, thus draining the entire basin above it. A shaft connects the eastern end of the tunnel with the surface. Water is brought to the mine by flumes from several points in the neighboring hills.

This system, however, was never put fully into operation, and mining since its installation has consisted in taking out ore left between the old levels and has been done only on a small scale. The mine at present consists of a large open pit, several hundred yards in extent and about 50 feet deep, near the north end of the basin. From the bottom of this pit a shaft 137 feet deep connects with the drainage tunnel; thus 137 feet of workable ground is left between the bottom of the pit and the level of the tunnel, and about half of this is untouched by former workings. Mining operations are also being conducted in small surface cuts north of the main pit.

The clays are for the most part residual from the upper Cambrian shale and are white, yellow, orange, brown, and black in color. In general they are stiff, but here and there are masses of yellow sandy clay or white sand or fragments of undecomposed sandstone. The black manganiferous clay generally occurs in separate beds, lenses, or irregular pockets, or interlaminated with the other clays, while the light-colored clays as a rule are intimately intermixed. Stiff orange and yellow clays are the most abundant and contain most of the ore. The residual clays are covered by a layer of drift averaging about 15 feet in thickness.



SECTION 1

SECTION 3

SECTION 2

SECTION 4

Figure 5.—Sections through the Crimora manganese deposit. (See fig. 4.) 1, Quartzite; 2, manganese-bearing clay; 3, surface drift. (After Hall.) Vertical scale, 1 inch = 600 feet; horizontal scale, 1 inch = several hundred yards.

The ore is hard and is of three varieties: (1) Kidney ore of bluish-black psilomelane in stiff orange and yellow clay; (2) irregular pockets of pyrolusite and psilomelane in manganiferous clay; and (3) replacements and cavity fillings of psilomelane and pyrolusite in sandy clay.

1. The kidney ore is most abundant and occurs in lumps ranging in diameter from a few inches to 10 inches. The lumps are of rounded, irregular shapes and bear nodular projections on the surface. At many places a number of kidneys are connected, making branching forms. The ore is coated with a thin layer of bright red clay, which is removed during the washing. The lumps are segregated in local

layers, lenses, and irregular bodies of clay separated by barren areas. (See fig. 6.) This ore is generally homogeneous in texture, showing little or no tendency toward concentric layering. Some of the bodies contain cavities lined with brown, sooty wad. but most of them are solid and hard.

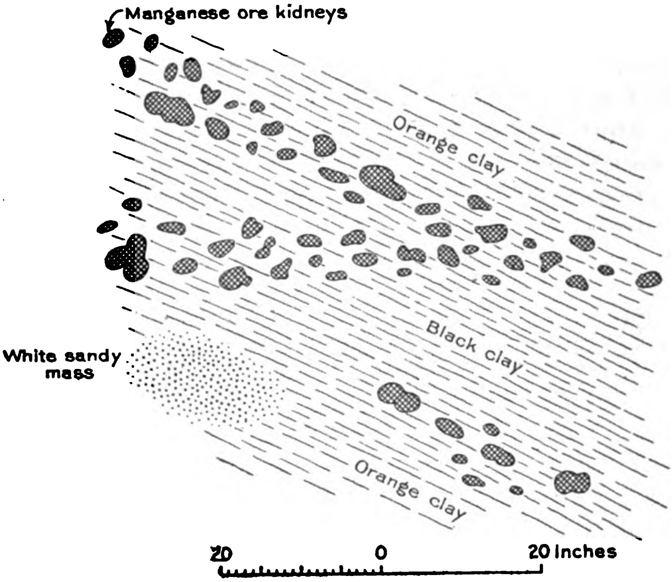


FIGURE 6.—Sketch showing distribution of manganese ore lumps in clay at the Crimora mine.

2. The bodies of ore in manganiferous clay are composed of both psilomelane and pyrolusite. They are very irregular in size and shape and grade into the clay, probably representing local areas of greater concentration.

3. The ore of the third type commonly occurs in yellow or brown sandy clay masses as fillings of seams and cavities and as irregular replacements. Psilomelane and crystalline pyrolusite are found in equal abundance, and as a rule occur in successive layers, the pyrolusite, being in the form of fine needles, transverse to the surface of the layer. (See fig. 7.) Here and there beautiful crystals of pyrolusite line small, irregular cavities. The ore masses are very irregular in shape and the largest are 6 inches or more in thickness. Small areas of sandy clay grading indefinitely into the ore are included locally in the ore masses. Replacement has taken place along cracks in the clay for half an inch on each side, plainly showing recent deposition.

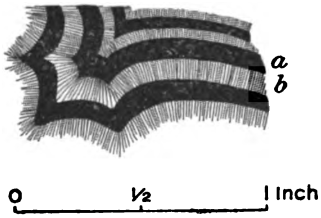


FIGURE 7.—Sketch showing concentric layers of pyrolusite and psilomelane. *a*, Psilomelane; *b*, pyrolusite.

Manganese oxide also occurs in beautiful dendritric forms and crystalline coatings in the underlying quartzite, as is shown in the material taken out of the drainage tunnel.

In the upper portion of the basin the ores are generally very ferruginous, but with depth the iron becomes less abundant.

The following are analyses of ore from the Crimora mine:

Analyses of manganese ore from the Crimora mine.[a]

	1.	2.	3.	4.	5.	6.
Mn	57.291	49.16	48.53	50.54	48.16	44.54
Fe	.373	1.75	1.99	1.96	4.57	3.26
SiO_2		9.80	10.20	10.12	10.30	14.00
P	.075		.103		.095	.087
Moisture		6.00	3.00	3.00	3.00	

[a] Penrose, R. A. F., jr., Manganese: Its usos, ores, and deposits: Ann. Rept. Arkansas Geol. Survey for 1890, vol. 1, 1893, p. 405; also Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 430.

Analysis 1 shows the composition of best quality of ore; the other analyses give averages of monthly shipments during 1887 and 1888.

The following table gives a complete analysis of Crimora ore:

Complete analysis of Crimora manganese ore.[a]

MnO_2	81.703
MnO	7.281
Fe_2O_3	.533
CoO	.354
NiO	.096
ZnO	.623
Al_2O_3	.896
BaO	.829
CaO	.880
MgO	.630
P_2O_5	.171
Na_2O and K_2O	.467
H_2O	3.405
SiO_2	2.132
Mn	57.291
Fe	.373
P	.075

Old Dominion mine.—The Old Dominion mine adjoins the Crimora mine on the southwest, occupying the southern part of the Crimora basin.

The workings have been mainly near the surface and the ore mined has been ferruginous. It occurs in clay in seams and irregular fragments that show a tendency to assume nodular forms. Ore like that in the Crimora pit will probably be encountered at greater depth.

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[a] Watson, T. L., Manganese oxides: Mineral Resources of Virginia, p. 248.

Watt property.—The Watt property is located in Augusta County, about 1½ miles east of Doom Crossing, a short distance from the foot of the Blue Ridge. The workings, consisting of several shafts, have been abandoned and the ore was not seen in place. From the dumps it appears that the ore is embedded in yellow sandy clay and that it is of the same variety as the Crimora ore of the third class, described above. It consists of psilomelane and crystalline pyrolusite in concentric layers, the psilomelane being the more abundant. The pyrolusite is in needles that lie transverse to the faces of the layers. Areas of sandy clay are included in the ore, and at the contact with it show partial replacement.

Lyndhurst mine.—The Lyndhurst mine, operated by the Metallic Alloys Company, of Elkton, Va., is in Augusta County, about 2½ miles south of Lyndhurst, 1 mile north of Sherando, and about 1 mile west of the foot of the Blue Ridge. The workings consist of several shafts, with drifts at four or five levels. The ore occurs at intervals in a pocket that has been tested to a depth of about 60 feet and a horizontal extent of about 300 feet. The ore consists of (1) small nodules of psilomelane scattered through yellow and variegated clay, and (2) irregular bodies of psilomelane in black manganiferous clay, which occurs as lenses and layers interbedded with the variegated clay.

The nodules in the variegated clay range from one-fourth inch to several inches in diameter, but are characteristically small and of irregular shape. In some spots they are packed close together, while elsewhere they may be scattered at intervals of 6 inches. The ore in the manganiferous clay is hard or soft and occurs in seams or coral-like masses, the largest a foot in diameter, though most of them are smaller. The interstices are filled with clay. Fragments of sandstone are common in the clay, and the ore is in places deposited around them and cements together the small fragments.

The ore is scattered, and much dirt has to be washed to obtain a small quantity of it. The extent of the deposit, however, seems to warrant the expense of mining and concentrating.

The following are analyses of ore from the Lyndhurst deposit:

Analyses of manganese ore from the Lyndhurst mine.[a]

MnO_2	93.06	86.77
Fe_2O_3	Trace.	2.98
SiO_2	.18	3.98
Al_2O_3	.91	2.81
CaO		Trace.
BaO	2.81	.31
H_2O	2.75	2.93
Loss	.29	.22
	100.00	100.00

[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 317.

Mount Torry property.—The Mount Torry property is in Augusta County, on the west slope of Torry Mountain, a spur of the Blue Ridge, about 6 miles south-southwest of Lyndhurst and 3 miles southwest of Sherando. The workings consist of a large number of old pits and a recent shaft and are scattered over an area a little over a quarter of a mile square. The deposits consist of manganiferous iron ore, the iron and manganese oxides being intimately intergrown. At many points the limonite occurs in fragments surrounded by psilomelane, which also penetrates it in veins. The psilomelane is mainly of the coral-like variety and is very hard. The ore occurs in irregular masses in yellow clay.

Kennedy tract.—The Kennedy tract is in Augusta County near the foot of the northern slope of Kennedy Mountain, a spur of the Blue Ridge, 4 miles east-southeast of Stuarts Draft. The workings consist of a large open pit, in which water at present conceals the main ore strata.

The ore is largely psilomelane, and occurs as kidneys in reddish and variegated light-colored clays. Nodular masses of limonite, with cores and intergrowths of psilomelane, are found near the surface. Here also occur hard, coral-like masses of ferruginous psilomelane with interstices filled with clay, seams of psilomelane in manganiferous clay, and crystals of pyrolusite lining small cavities in red clay.

The following is an analysis of ore from the Kennedy tract:

Analysis of manganese ore from the Kennedy tract.[a]

Mn	43.30
Fe	3.88
S	.083
P	.052
Ba	6.93
SiO_2, H_2O, etc	17.69

Vesuvius mine.—The Vesuvius mine, operated by the Manganese Corporation of Virginia, is in Augusta County, about 1½ miles northeast of Vesuvius. The workings consist of several old pits, an abandoned shaft with drifts, and two recent shafts which are still being sunk (1908). The ore could be examined only in the old surface pits formerly worked under the name of the Fauber mine. Here it occurs most abundantly as a cement in chert and sandstone breccias, but is also found as kidneys embedded in clay. The breccia ore occurs in large masses several feet in diameter in brown or yellow clay. The manganese may be in the form of either black psilomelane or gray crystalline pyrolusite, but is generally the former. The fragments consist for the most part of white chert, which frequently have been partly replaced near the surface by manganese oxide. Where psilomelane is the cement, the breccia masses often have a thick botryoidal coating of this ore containing few or no rock fragments.

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[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 318.

The kidneys vary considerably in size, though generally they average over 2 or 3 inches in diameter. As a rule they are composed of massive black psilomelane and are solid and textureless, but some of them include small particles of rock, thus grading toward breccia ore.

Soft ore occurs in irregular streaks and patches through the clay. Some of the clay retains the original shaly structure, and in such clay manganese oxides have penetrated along bedding planes and in veins across them.

Several bodies of manganiferous iron ore in which psilomelane occurs in small irregular masses through the brown iron ore are also found in the pits.

Mine bank and Red Mountain.—At Mine bank and Red Mountain, 6 miles northeast of Vesuvius, large deposits of manganiferous iron ore are found. Both localities are south of St. Mary River, several miles up in the Blue Ridge. During the eighties considerable iron ore was mined at Mine bank for use in the old Cotopaxi furnace, but operations were finally suspended on account of the high manganese and silica content of the ores.

Both deposits consist of large lens-shaped bodies of ore, some of them 50 or 60 feet in extent. Manganese oxide, largely psilomelane, occurs in the iron ore in small irregular pockets and lenses, ranging up to 4 or 5 inches in the longer diameter. The deposit was evidently formed by successive deposition of iron and manganese oxides, the iron in layers and the manganese in discontinuous lenses. Stalactites of psilomelane are frequently found in cavities. The following is an analysis of the ore:

Analysis of manganiferous iron ore from Mine bank.[a]

Fe	41.12
Mn	8.22
P	.26
SiO_2	14.83

Blue bank.—Blue bank is about 3 miles northeast of Vesuvius, near the west end of Cellar Mountain. The workings consist of a series of open cuts and tunnels some distance apart. The ore mined was a dark brown to blue, highly manganiferous iron ore. In the principal type of ore manganese and iron oxides occur thoroughly intermixed, and psilomelane and pyrolusite are found separately lining cavities in it. The ore apparently occurs in large masses.

Kelly bank.—Kelly bank is about 1 mile northeast of Vesuvius. The ore mined here has been largely iron ore, but manganese ores are associated with it.

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[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 319.

Midvale mine.—The Midvale mine is located on top of a ridge about 1 mile northeast of Midvale, Rockbridge County. The workings consist of an incline, a shaft, and a few test pits. Considerable ore is said to have been mined here, but the poor condition of the incline prevented an investigation of the deposit. It is said to have been largely wash ore disseminated through clay.

Gowens, White, and Deal banks.—Several mixed manganese and iron ore deposits are found at the foot of the Blue Ridge, between Lithia and Nace in Botetourt County. Ores have been mined at Gowens bank, White bank, and Deal bank. The manganese ore is largely blue granular pyrolusite occurring in small masses in brown sandy clay. The iron ore occurs separately in large masses.

Stoner mine.—The Stoner mine is in Botetourt County about 1 mile northeast of Troutville. The workings consist of several old pits and a recent shaft. Very little ore has been taken out and this consists of black psilomelane in small irregular masses embedded in yellow clay. The following is an analysis of ore from this vicinity:

Analysis of manganese ore from the Chapman property.[a]

Mn	45.80
Fe	3.06
P	.164

Houston mines.—The Houston mines are in Botetourt County about 3 miles northeast of Troutville. The workings consist of two large banks about one-half mile apart near the foot of the western slope of the Blue Ridge. This property was first worked as a source of manganiferous iron ore, but pure manganese ores were encountered in the lower part and attention was turned to them.

The upper part of the banks consists of pink, orange, yellow, and brown clays with local masses of partly decomposed sandstone. Toward the lower part the brown clays prevail and at the bottom there are horses of brown sandstone. Masses of dark manganiferous clays occur with the brown clays in the lower portion. The upper clays contain mainly fragments of brown iron ore, but locally there are small irregular masses of psilomelane, or of psilomelane and pyrolusite.

The principal portion of the manganese ore, however, occurs in the lower brown and manganiferous clays around the sandstone horses and as seams and replacements in the sandstone itself. This ore is in the form of rather soft and friable blue granular pyrolusite. With it are associated small amounts of crystalline pyrolusite in the form of coarse needles. The granular ore appears to be largely a replacement, and the needles to be a cavity filling. Some of the ore is in irregular masses and some in definite layers. A good deal of partly replaced material is generally associated with it and grades into it.

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[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 321.

The following are analyses of ore from the Houston mines:[a]

Analyses of manganese and manganiferous iron ore from the Houston mines.

	1.	2.	3.	4.
Mn	44.312	7.277	59.870	39.00
Fe	12.325	47.15	.50	12.00
P	.101	.061	.049	....
SiO_2	5.470	8.03	2.30	....

1. Manganese ore.
2. Manganiferous iron ore.
3. Selected sample.
4. Average of monthly shipment, 1884-85.

NORTHWESTERN VIRGINIA.

GENERAL STATEMENT.

Local deposits[b] of manganese and manganiferous iron ore occur in the region of parallel ridges west of the Blue Ridge district, where they are found in association with the Oriskany iron ores. The ores occur largely in the Oriskany horizon, but are said[c] to occur also in the "Hudson River" (Martinsburg) shale and the Clinton formation. They are nearly always associated with brown iron ore. (See p. 51.) The most important of these deposits occur in the Great North and Massanutten mountains, in northwestern Virginia, but minor deposits are present to the southwest.

DESCRIPTIONS OF MINES AND DEPOSITS.

Paddy Mills mine.—The Paddy Mills manganese mine is in the southwest corner of Frederick County. It occupies a conical hill about a square mile in extent and 150 feet above the surrounding country. The ore is chiefly soft pyrolusite embedded in limestone strata, but hard ore also occurs. The following is an average analysis of hard ore associated with the soft ore:

Analysis of manganese ore from the Paddy Mills mine.[d]

Mn	50
Fe	4
P	0.09-0.10

Cedar Creek.—Recently manganese deposits have been reported from Cedar Creek in the southeastern part of Frederick County, but the extent of these is not known.

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[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 320.

[b] Idem, pp. 324-327.

[c] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 434.

[d] Weeks, J. D., Mineral Resources U. S. for 1885, p. 324.

Van Buren furnace.—At Van Buren furnace,[a] in the northwestern part of Shenandoah County, an extensive deposit of manganese is found with the iron ores. The ore was reported as accompanying the Oriskany horizon in more or less continuous pockets over an area 3 miles long. The main deposits are at the western end of Cupola Mountain, but outcrops occur in the broken hills that prolong it to the southwest. The ore was reported to contain 70 per cent manganese oxide.

Powells Fort.—The Powells Fort manganese deposits[b] are located on Northeast Massanutten Mountain at Powells Fort, in the eastern part of Shenandoah County, and extend slightly into the western part of Warren County. The ore was reported as very pure crystalline pyrolusite, and as occurring in two parallel beds over a mile in length, only one of which has been developed. This bed was said to be 4 to 7 feet thick and to have a conglomerate for a hanging wall and a sandstone for a foot wall. The following are analyses of manganese ore from Powells Fort:

Analyses of manganese ore from Powells Fort.[a]

	1.	2.	3.	4.
Mn oxide	94.30			
Fe_2O_3		0.43		
SiO_2	1.78	3.78	9.20	1.50
Fe_2O_3, CaO, and Mn	.50			
Al_2O_3	1.10	.25		
BaO	1.30	.42		
Moisture	.28	.37		
Undetermined	.74			
O, loss, and undetermined		34.09		
Mn		60.66	48.59	59.302
Fe			3.07	.844
P			.349	.190
S			.12	
	100.00	100.00		

[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 326.

The following description of the manganese mines of Powells Fort in the Massanutten Mountain was furnished the writer by Mr. R. J. Holden.[c]

> Powells Fort, or Little Fort Valley, lies in the eastern corner of Shenandoah County, Va., southeast of Strasburg and Woodstock. Structurally this valley is a syncline of Silurian and Devonian sediments and constitutes the most northerly syncline of the Massanutten synclinorium. This valley carries ores both of manganese and of iron, which have been mined at several points within an area 5 miles long, the iron for use in the local Mine Run furnace and the manganese for shipment. The principal manganese mines are the Baltimore mine and the Philadelphia mine.
>
> The Baltimore mine is about 6 miles east of Woodstock and one-third mile west of the Mine Run furnace, near the southwest end of the Little Fort Valley. It is reported to have been opened in 1880 and equipped with concentrating machinery. Apparently the mine was not worked for any considerable time. The machinery is said

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[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 324.

[b] Idem, p. 325.

[c] Holden, R. J., unpublished notes, 1909.

to have been removed about 1901, but the mine is reported to have been worked for eighteen months in 1907 and 1908, the ore being sorted by hand. The ore occurs on the outcrop of the southeast limb of the syncline in a northeasterly dipping sandstone and in an overlying conglomerate. A. C. Spencer[a] refers to "a valuable deposit of manganese" in the "Monterey" (Oriskany) sandstone in Little Fort Valley under the name of the Powells Fort mine. This is evidently the same as the Baltimore mine. He describes the mine as follows:

"The manganese ore, which is a well-crystallized oxide, appears to occur in a veinlike body along the bedding of the sandstone, which here dips about 45 degrees to the northwest. No clay is present with the ore, as is the case in the deposits along the Blue Ridge, but it is found coating the walls of the crevice in which it occurs, and often as a cement binding fragments of conglomerate and penetrating the contiguous sandstone. The width of the vein varies from 2 to 9 feet, with occasional pinches where it is cut out entirely."

The lower sandstone is a white or gray loose-textured rock with various sizes of grain and is more or less impregnated with blue manganese. This produced the low-grade siliceous ore, mined from a shaft said to be 20 feet deep, with drifts in the bottom. The overlying conglomerate carries pebbles one-half inch and less in diameter and has a decidedly vitreous appearance. This carries the high-grade ore and has been worked in a V-shaped open cut for about 400 feet on the strike and 10 to 20 feet deep, and to some extent in underground workings which are said to have a maximum depth in a shaft of 120 feet. At the surface the conglomerate is seen to be fractured and to have crevices up to 4 inches in width containing brown wad and some crystalline dark-colored hard manganese, but no clay. Lining the cavities in the ore there are distinct crystals of manganese oxide 1 to 2 millimeters in diameter, of undetermined crystal form but apparently orthorhombic. In mining it is reported that the method was to follow the crevices which carried wad, and in this way cavities were found which carried as high as half a ton of high-grade ore.

The Philadelphia mine is about a mile and a half northeast of the Baltimore mine and a half mile west from Mud Hole Gap. It is in the same syncline with the Baltimore mine, but apparently on the northern limb of the syncline, although the stratigraphic relations were not studied. The mine is near the base of Three Top Mountain and in a talus of clay and sandstone bowlders. The main visible opening is a small circular pit 15 feet deep. This shows a soft blue manganese which crumbles to a powder on touching. There are some other workings, including tunnels. It is reported that several hundred tons of manganese were shipped, but apparently the powdery condition has prevented satisfactory saving of the ore.

In the Oregon iron mine, which is in the same valley with these manganese mines and some 4 miles northeast of the Baltimore mine, there is abundant blue hard manganese and some manganiferous iron ore. This mine consists of a number of shallow cuts, but much of the ore was taken from the surface without much mining. The stratigraphic relations are not evident, but apparently this mine is on the strike of the formation of the Baltimore mine, and the relations appear to be the same.

In the Oriskany iron-ore mines of Virginia the iron ores are not uncommonly locally high in manganese, and at places in the ore horizons where iron is absent, or present in small quantities only, it is not infrequently the case that the rocks are more or less impregnated with manganese. There is strong evidence that these materials were leached from the overlying black Devonian shale. It is not improbable that the iron and manganese of the ores of Little Fort had the same origin. The explanation of the peculiar character of the deposit in the Baltimore mine is to be found in the exceptional character of the Oriskany sandstone at this point. The clean fractures furnished cavities where the manganese could be precipitated without being contaminated by the phosphorus of the associated material.

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[a] Spencer, A. C., The geology of Massanutten Mountain in Virginia, p. 12.

NEW RIVER REGION.

GEOGRAPHY AND TOPOGRAPHY.

The ores of the New River region occur in several belts south of Pulaski, Wytheville, and Marion in Smyth, Wythe, and Pulaski counties in southwestern Virginia. (See Pl. II.) The region consists of short parallel east and west ridges with intervening valleys. It is drained on the east by Cripple Creek, the waters of which flow eastward into New River and thence northward into the Ohio by way of the Kanawha. On the west the district is drained by South Fork of Holston River, which flows southwestward into the Tennessee. The principal manganese area is southeast of Marion, between that place and the Iron Mountains. In this area there are several parallel ridges and valleys. First southeastward from Marion is Pond Mountain, beyond which is a small valley known as Currin Valley. On the south side of Currin Valley is Brushy Mountain, and south of this a level region 2 or 3 miles wide and 6 or 8 miles long known as Rye Valley. Beyond Rye Valley are the Iron Mountains.

GEOLOGY.

The district is best known for its limonite deposits, with many of which there is associated a small amount of manganese ore. In some localities the manganese ore is abundant enough to form a manganiferous iron ore, or even a ferruginous manganese ore. The ore-bearing rocks are of Cambrian and Ordovician age, with a succession similar to that farther northeast, in the valley of Virginia.[a]

General succession of rocks in southwestern Virginia.

- Mississippian:
    - Pennington shale.
    - Newman or Greenbrier limestone.
    - Pulaski shale.
    - Price sandstone.
- Devonian:
    - Grainger shale.
    - Chattanooga shale.
- Silurian:
    - Giles formation.
    - Clinton (Rockwood) formation. (Carries fossil hematite.)
    - Clinch sandstone.
- Ordovician:
    - Bays sandstone.
    - Sevier shale.
    - Moccasin limestone—Tellico sandstone.
    - Chickamauga limestone—Athens shale.
        - Holston marble lentil.

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[a] Keith, A., Cranberry folio (No. 90); Campbell, M. R., Pocahontas folio (No. 26); Tazewell folio (No. 44), and Bristol folio (No. 59), Geol. Atlas U. S., U. S. Geol. Survey.

Cambro-Ordovician.
  Knox dolomite.
Cambrian:
  Nolichucky shale.
  Honaker limestone.
  Watauga shale.
  Shady limestone. (Carries valley brown ore.)
  Erwin quartzite. (Carries mountain brown ore and manganese ore.)
  Hampton shale.
  Unicoi sandstone.
Pre-Cambrian:
  Crystalline and metamorphic rocks.

The Shady limestone is the principal surface rock in the northern part of the manganese areas, the underlying sediments being more prominent to the southeast. The contact between the Paleozoic rocks and the crystalline rocks of the Piedmont region is on the south slope of the Iron Mountains, which are just south of the district. There has been a great deal of thrust faulting, bringing about complexity of areal distribution of the rocks. The fault planes[a] dip southeast, and the general dip of the sediments is in the same direction. There has been considerable folding, causing the formation of a number of east and west anticlinal ridges. The ores are associated mainly with clays derived from the Erwin quartzite, though locally small deposits occur in clays of the Shady limestone.

OCCURRENCE OF THE ORES.

The manganese ores of the New River region are somewhat different in their associations from the ores of the Blue Ridge region, although areally and stratigraphically they occupy a similar position with regard to the crystalline rocks. In the principal deposits the ores are found in large masses in variegated clay. Though in general irregular, these masses tend roughly to take the form of vertical lenses several feet thick. They consist of a mixture of psilomelane and limonite in varying proportions with a large amount of decomposed sandstone and clay in the form of small fragments and irregular masses. The ore is deposited around the fragments, and in veins through them, and in part replaces them. There are many small irregular cavities, into which protrude numerous nodular points of psilomelane. Where the clay is sandy, as in the Currin Valley mine, the ore contains an abundance of sand grains. The relation between the iron and manganese is complex, though in general the manganese penetrates deeper into the mass. Generally they interpenetrate coarsely and can be easily distinguished in a specimen, but in some places they are intimately mixed. Limonite commonly lines cavities in the manganese ore, and in such places it is clearly a later deposition.

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[a] Holden, R. J., The brown ores of the New River-Cripple Creek district, Virginia: Bull. U. S. Geol. Survey No. 285, 1906, p. 190.

Besides these large masses, manganese is found in a few places as small, irregular, nodular bodies disseminated through yellow and brown clay. These have not been found to form workable deposits.

DESCRIPTIONS OF MINES AND DEPOSITS.

Umbarger mine.—The Umbarger mine is situated in Smyth County about 1½ miles east of Sugar Grove, near the headwaters of South Fork of Holston River. It is south of Brushy Mountain, in the eastern portion of Rye Valley. The main workings consist of several small pits in red, brown, yellow, and manganiferous clays, but considerable trenching and drilling has been done as exploration work. The principal occurrence of ore is in the form of large masses 4 or 5 feet thick, consisting of a porous mixture of psilomelane and brown iron ore, deposited around decomposed sandstone fragments so as to form a breccia. Many of the fragments have been largely replaced by ore. The masses are generally somewhat elongated and stand vertically in red and brown clay. Ore also occurs in the form of gray and black psilomelane in small irregular masses scattered sparingly through red and yellow clay. They are generally less than 3 or 4 inches in diameter, and have irregular surfaces with numerous small nodular projections. Deposits are scattered over an area of perhaps 20 or 30 acres.

Currin Valley mine.—The Currin Valley mine is in Smyth County, about 1½ miles south of Attoway. It consists of several large cuts or banks on the north side of Currin Valley. The banks are in light-colored clay, which here and there contains masses of partly decomposed sandstone. The ore mined has been mainly brown iron ore, but manganese ore is associated with it. The manganese is largely in the form of psilomelane and occurs as an infiltration in sandstone and clay in irregular streaks and seams. It cements grains of sand and small fragments of sandstone, and contains also masses of clay. It is generally coarsely intermixed with limonite, the association in many places being such as to suggest that limonite is a later deposition. The limonite commonly lines cavities and coats masses of psilomelane; the psilomelane penetrates the ore masses irregularly. Rarely, however, finely crystalline pyrolusite is found filling cavities in the limonite, so as to suggest that this mineral is of later origin than the iron ore.

Other deposits.—Besides the Umbarger and Currin Valley mines, numerous other small deposits of manganese and manganiferous iron ore have been discovered in the New River district. Many of these were encountered in the iron-ore deposits and have been mined;

others are mere prospects. Among them are deposits at the Atkins mine, southeast of Attoway, Smyth County; at the Walker and Tate properties, north of Sugar Grove, Smyth County; at Razor bank, Rye Valley, Smyth County; on Chestnut Ridge, 6 miles from Seven Mile Ford station, Smyth County; at the Eagle Cliff mine, near Ivanhoe, Wythe County; at several localities in Lick Mountain south of Wytheville, Wythe County; at the Glade bank, 4 miles southwest of Max Meadows, Wythe County; at Noble Furnace, Wythe County; near Allisonia, Pulaski County; and on Macks Mountain, 4 miles east of Radford Furnace, Pulaski County.

Analyses.—The following are analyses of ore from the New River district:

Analyses of manganese ore and manganiferous iron ore from the New River district.[a]

	1.	2.	3.	4.	5.	6.	7.	8.
Mn	52.55	17.28	44.05	44.46	10.18	9.91	14.78	4.97
Fe	4.52	36.75	8.20	7.40	40.10	45.32	39.97	50.45
P	.18	.23	.085	.213	.536	.086	1.074	.444
SiO_2	2.36	23.42	6.40	5.40	10.52	1.76	5.84	5.44

	9.	10.	11.	12.	13.	14.	15.
Mn	3.15	41.89	57.67	51.05	44.60	24.85	32.55
Fe	49.05	2.57	1.98	2.92	3.96	2.72	3.61
P	.179	.035	.009	.161	.45	.05	.097
S		.09	.067	Trace.	Trace.	Trace.	.030
SiO_2	10.77					47.30	27.86
Insoluble		4.05	1.85	4.32	15.81		

[a] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 432-433; also Mineral Resources U. S. for 1885, pp. 322-323; and Watson, T. L., Manganese oxides: Mineral resources of Virginia, p. 255.

1. From Deans Branch, south of Pond Mountain, Smyth County.
2. From Currin Valley on the west prong of Staleys Creek, Smyth County.
3. From the Atkins property, Smyth County.
4. From the Umbarger mine, Smyth County.
5. From Razor bank, Rye Valley, Smyth County.
6. From Glade Mountain, near Marion, Smyth County.
7. From Macks Mountain, 4 miles east of Radford Furnace, Pulaski County.
8. From Glade manganiferous iron-ore bank, 4 miles southwest of Max Meadows, Wythe County.
9. From Noble Furnace, Wythe County.

10-13. From Lick Mountain, near Wytheville, Wythe County.
14, 15. From Cripple Creek, 8 miles from Wytheville, Wythe County.

NORTHEASTERN TENNESSEE.

GENERAL STATEMENT.

Manganese and manganiferous iron ores occur in the western part of the Appalachian Mountains, in eastern Tennessee and western North Carolina, in a belt extending from Virginia to Georgia. The principal deposits, however, are in northeastern Tennessee.

Two principal groups of deposits are known in the northeastern Tennessee region—those of Shady Valley, Johnson County, and those of Newport and Del Rio, Cocke County. Small deposits have been reported from Carter, Unicoi, Greene, and Sevier counties, Tenn., and the adjoining counties of Madison and Mitchell in North Carolina.

The following is a general section of the Cambrian rocks of northeastern Tennessee, after Keith:[a]

Cambro-Ordovician: Knox dolomite.
Cambrian:
  Nolichucky shale.
  Maryville limestone
  Rogersville shale } Honaker limestone.
  Rutledge limestone
  Watauga shale.
  Shady limestone.
  Hesse quartzite—Erwin quartzite.
  Murray slate
  Nebo quartzite } Hampton shale.
  Nichols slate
  Cochran conglomerate
  Hiwassee slate } Unicoi formation.
  Snowbird formation
Archean:
  Granite and gneiss.

The iron ores of eastern Tennessee and western North Carolina are very largely associated with the Shady limestone. A large proportion of the manganese ores also occur in connection with these, for instance the ores of Shady Valley. Other deposits, however, which are more purely manganese, such as those around Newport, occur in residual clays of shales and quartzites below the Shady limestone.

SHADY VALLEY.[b]

GEOGRAPHY AND GEOLOGY.

Shady Valley is in the extreme northeastern corner of Tennessee. It runs in a general northeast and southwest direction and constitutes the northeastern portion of the valley between Holston Mountain on the northwest and Iron Mountain on the southeast. It varies in width from 3 miles to less than half a mile.

Shady Valley is drained by Beaver Dam Creek, which flows northeastward into South Fork of Holston River. The part of the main valley southwest of Shady Valley is drained southwestward by Stony Creek.

The Holston Mountains consist largely of quartzite or sandstone (Erwin quartzite), but on their lower slopes associated shales and limestones (Shady limestone) appear. These, as well as the upper part of the quartzite, are locally very much decomposed and exist at the surface as clay with local fragments of undecomposed rock. The formations are all of Cambrian age.

OCCURRENCE OF THE ORES.

The ores of Shady Valley, mainly brown iron ores, subordinately manganese, occur in residual clays of the quartzite, shale, and limestone. The iron ores have been worked for a long time, but the manganese ores have been merely prospected. The manganese occurs as steel-gray or black amorphous psilomelane in porous masses of stalactitic branches, and in kidneys. Crystals of pyrolusite line some of the cavities in the massive ore.

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[a] Keith, A., Roan Mountain folio (No. 151), Geol. Atlas U. S., U. S. Geol. Survey, 1907.

[b] Penrose, R. A. F., Jr., Manganese: Its uses, ores, and deposits: Ann. Rept. Arkansas Geol. Survey for 1890, vol. 1, 1893, pp. 414–416.

The iron and manganese ores are found interbedded in lenticular layers or pockets. In some places they occur together in the same pocket, and elsewhere they are separate. The iron-ore beds are a few inches to 10 feet thick; the manganese ore beds are a few inches to 3 feet thick.

The most important showings of manganese in Shady Valley[a] are at the Heberlin mine and its vicinity. About 800 tons of ore, which is mainly psilomelane, has been taken out, but none has been shipped. At the Wright opening near the head of the valley ore occurs in the massive form in a bed 6 feet thick. About 150 tons have been mined. Another deposit occurs in a small stream about a mile from the Wright opening, where a ledge of manganese ore 4 feet wide and 6 feet deep is exposed. Manganese ore has also been found in several places on the Sheafer property in the lower end of the valley, and at numerous localities in association with iron ore. Among the latter it occurs principally at the King, Blevins, and Silver banks.[b]

ANALYSES.

The following are analyses of ores from Shady Valley[a] and vicinity:

Analyses of manganese ores from Shady Valley.

	SiO_2.	Fe.	Mn.	P.
Heberlin mine	1.62	4.6	51.05	0.075
Do	1.1	3.0	55.00	.099
Do.[a]	1.30	2.085	53.735	.008
Alexander Coles	1.4	2.3	53.09	.177
Wright bank	7.6	7.1	41.44	.066
Sheafer bank	4.12	5.2	50.25	.16
King bank	1.7	16.1	40.87	.052

[a] Birkinbine, John, Mineral Resources U. S. for 1900, p. 124.

Manganese ores also occur in the iron-ore banks of Stony Creek valley, Johnson County, southeast of Shady Valley. The following is an analysis of ore from the Hodge mine near the head of the valley:

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[a] Weeks, J. D., Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, pp. 202-203.

[b] Willis, Bailey, Tenth Census U. S. (1880), vol. 15, Mining industries, pp. 344, 345.

Analyses of manganiferous iron ore from the Hodge bank.[a]

SiO_2	3.38
Fe_2O_3 (Fe, 34.28)	48.95
Al_2O_3	2.38
MnO	2.72
MnO_2	32.29
CaO	0.56
MgO	0.17
FeS_2	0.041
NiS	0.18
CoS	Trace.
CuS	Trace.
CO_2	0.25
SO_3	0.02
P_2O_5	0.166
C	0.04
H_2O-	1.14
H_2O+	7.89
	100.177

NEWPORT REGION.

GENERAL STATEMENT.

The region around Newport and Del Rio, Tenn., occupies the southwestern portion of the manganese belt, extending northeastward to Shady Valley. Newport is on the southeastern border of the Appalachian Valley near the first outliers of the Unaka Range. The manganese area extends from there to Del Rio, which is farther up in the mountains. The region is drained by French Broad and Big Pigeon rivers.

The rocks in the vicinity of Newport and Del Rio are of Cambrian and Ordovician age. The ore deposits occur in residual clays derived from shale, limestone, and quartzite in the Cambrian.

The manganese ores are either soft or hard. The soft ores are in the form of irregular pockets and seams and are generally associated with manganiferous clay, but also occur with other clays. The hard ore is largely psilomelane and occurs in kidneys and irregular masses. The kidneys as a rule are small and are scattered through the clay. The irregular masses are of various sizes and occur together in pockets or lenses in the clay. Much of the clay is sandy, and in such places the associated ores contain numerous grains of sand and small sandstone fragments.

DESCRIPTIONS OF MINES AND DEPOSITS.

Yellow Springs mine.—The Yellow Springs mine is on English Mountain, about 5 miles southwest of Newport. It consists of an open pit in brown clay, derived from Cambrian shale and quartzite. This contains streaks and irregular masses of red, yellow, and dark manganiferous clay and pockets of sand. Surface fragments of quartzite are abundant. Both soft and hard ores occur and are associated with the more argillaceous material. The soft ore occurs in both the brown and the manganiferous clays in streaks and irregular pockets containing seams of clay. In places it is found in small specks grouped together into pockets. The hard ore consists of psilomelane in two forms—kidneys and irregular masses. The kidneys are very irregular in shape, varying up to 4 inches in diameter, though generally small, and are found scattered through the different clays and also through the soft-ore pockets. The irregular masses generally have botryoidal surfaces and contain cavities filled with clay. They vary in size up to a foot or more in diameter, and occur together in pockets or lenses in the clay.

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[a] Willis, Bailey, op. cit., p. 345.

Jones and McMahon properties.—The Jones and McMahon properties are about one-half mile northeast of the Yellow Springs mine. A very sandy ore occurs here in the form of irregular and stalactitic masses, as float.

Raines property.—About one-half mile northeast of these is the Raines property. Manganese oxide occurs locally in specks and wormlike stringers, replacing brown sandstone fragments embedded in orange clays. In places the replacement has gone so far that the fragments have become black. Irregular masses of psilomelane also are found scattered through the clay.

Other deposits.—Other deposits in this district are reported from Neddy Mountain and Long Creek, 3 miles and 5½ miles, respectively, east of Bridgeport; from Del Rio, Wolf Creek, and Cosby, all in Cocke County.

MINOR LOCALITIES.

Ore has been found at several localities in Unicoi County,[a] but the pockets are too far apart to make mining profitable. It is reported as having an average percentage of 46.73 of manganese and 0.212 of phosphorus. The deposits[b] occur at the contact of the Shady limestone with the underlying Erwin quartzite at two localities, one 2½ miles N. 70° E. of Unicoi City, and the other the same distance and direction from Erwin.

In Greene County manganiferous iron ore containing 48.87 per cent iron, 6.52 per cent manganese, and 1.031 per cent phosphorus occurs at the Stephens mines[c] near Hayesville furnace. Ore has also been found 11 miles from Greeneville in the Unaka Range.[d]

From North Carolina manganese ores are reported from Mitchell County, and near Hot Springs in Madison County, where they occur in association with iron ores in Cambrian rocks. The following are analyses of ores from Hot Springs:

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[a] Weeks, J. D., Sixteenth Annual Rept. U. S. Geol. Survey, pt. 3, 1895, p. 424.

[b] Keith, Arthur, personal communication.

[c] Willis, Bailey, op. cit., p. 337.

[d] Penrose, R. A. F., jr., op. cit., p. 416.

Analyses of ores from vicinity of Hot Springs, N. C.[a]

Mn	48.93	49.86	41.71	38.27	42.80	48.01	44.09
Fe	2.65	12.40					
P	.17		.103	.064	.187	.157	.254
SiO_2	10.12						
Gangue		.86					
MnO_2		78.87					
Mn_2O_3		17.72					

[a] Weeks, J. D., Eleventh Census U. S. (1890), Mineral industries, pp. 304-305.

CARTERSVILLE DISTRICT.

GEOGRAPHY AND TOPOGRAPHY.

The Cartersville district is in northwestern Georgia, northeast, east, and southeast of Cartersville, Bartow County. The manganese-bearing area is about 15 miles long in a north and south direction and 5 miles wide. It is drained by Etowah River, which flows westward into Coosa River and thence by way of the Alabama into Mobile Bay.

The region contains a number of detached hills and ridges with smooth and rounded slopes and broad intervening valleys. The ridges are generally wooded, while the valleys are cultivated, cotton raising being the chief industry. The district ranges from 700 to 2,200 feet above sea level, but the difference in elevation between the hill tops and valley bottoms is generally less than 1,000 feet. Northward, however, the difference in elevation becomes more pronounced as the Unakas and other high Appalachian ranges are approached. The manganese ores occur mainly on the slopes of the ridges.

GEOLOGY.

The rocks of the Cartersville district range in age from pre-Cambrian to Ordovician, with the following succession:

- Cambro-Ordovician: Knox dolomite.
- Cambrian:
  - Conasauga shale.
  - Rome formation.
  - Beaver limestone.
  - Weisner quartzite.
- Metamorphic: Conglomerate, slate, and schist. (Ocoee group.)
- Crystallines:
  - Granite and gneiss.
  - Amphibolite schist.

The contact between the metamorphic and Cambrian rocks is marked by the Cartersville fault, just east and south of the manganese-bearing area. (See fig. 8.) East and south of the Cartersville fault are the metamorphic and crystalline rocks, while to the north and west are the Paleozoic rocks.

The Weisner quartzite[a] is exposed in an irregular belt just west of the fault and forms a more hilly area than the formations to the west. It is a brown vitreous quartzite with some beds of fine conglomerate and siliceous shale. The thickness is said to be probably 2,000 to 3,000 feet, but may be considerably more, as the quartzite is very complexly folded and faulted, and the base is nowhere exposed. The residual material derived from the Weisner quartzite is sandy brown, yellow, and variegated clay.

The Beaver limestone forms a belt west of the quartzite exposures. It is seen at few points at the surface, but drilling has shown it to be a gray crystalline dolomitic limestone, shaly in places and containing masses of chert. Near the surface the limestone is decomposed into dark-red residual clay, with chert fragments. In many places the clay contains also quartzite fragments derived from the Weisner quartzite. The thickness is probably between 800 and 1,200 feet.

The Conasauga and Rome formations constitute a great thickness above the Beaver limestone and form the bed rock in the district west of the Beaver limestone area.

OCCURRENCE OF THE ORES.

The manganese ores of the Cartersville district are found in the residual clays of both the Weisner quartzite and the Beaver limestone, but mainly of the former. They occur scattered throughout the area covered by these clays, but workable deposits are only locally developed. Manganiferous iron ores occur at various places, but they are comparatively unimportant.

The ore is of four varieties: (1) Kidney ore, consisting largely of pyrolusite, rarely of psilomelane, and showing concentric structure; (2) irregular masses, either psilomelane or pyrolusite, or a mixture of the two; (3) breccia and replacement ore with chert or sandstone fragments; and (4) seams and irregular pockets of soft ore with local hard masses. All of these different types occur scattered through clay, grouped into local deposits, the second and fourth being more commonly associated with black manganiferous clay. Generally several types of ore occur together in the same deposit.

1. The kidney ore is largely pyrolusite and occurs in three different forms: (*a*) The most common type is that consisting of granular and finely crystalline pyrolusite in successive concentric layers. The crystalline pyrolusite may be in the form of fine needles, but is generally in irregular aggregates. Commonly the layering is obscure

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[a] Hayes, C. W., and Eckel, E. C., Iron ores of the Cartersville district, Georgia: Bull. U. S. Geol. Survey No. 213, p. 233.

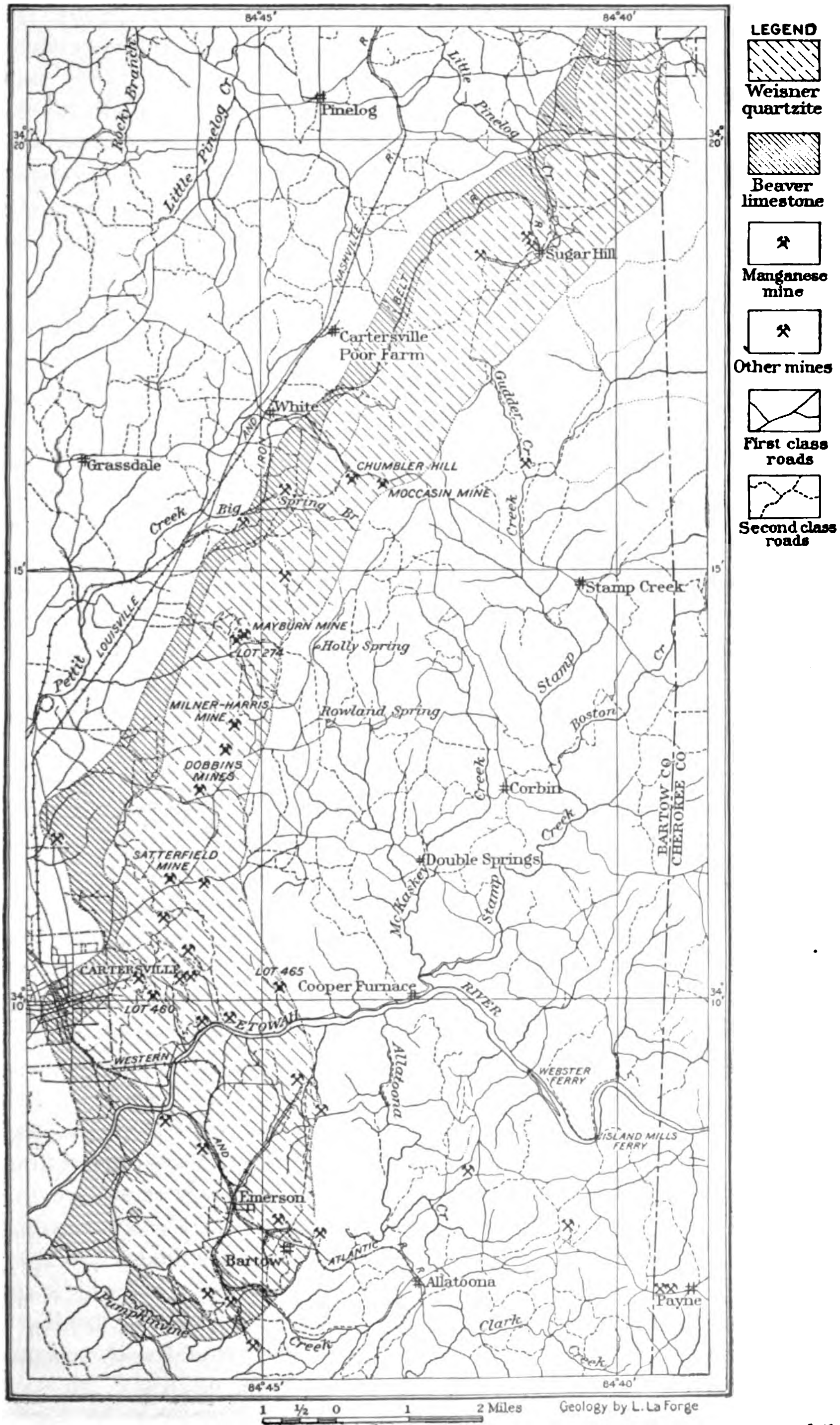

FIGURE 8.—Map showing the principal manganese mines in the Cartersville district, Georgia, and the probable extent of the ore-bearing areas.

and is interrupted by cavities lined with fine crystals of pyrolusite. (*b*) Another type of kidney ore consists altogether of thin concentric layers of blue, finely granular pyrolusite. (*c*) The third type is composed largely of coarsely crystalline pyrolusite in concentric layers. The layers range up to one-third inch in thickness and are composed of short, coarse, parallel needles arranged transversely. Commonly several kidneys become cemented together into a single mass, and thus grade into the second variety of ore—that is, the irregular-mass ore.

The kidneys are embedded in clay, in some places being very closely grouped and in other places scattered at considerable intervals. They are generally associated with other types of ore. Separate lumps range up to 4 or 5 inches in diameter, but kidneys that are cemented together may be in masses a foot or more in diameter.

2. The irregular masses of ore vary up to a foot or more in diameter, and are scattered through the clay or segregated into pockets. They consist either of pyrolusite, of psilomelane, or of a mixture of the two, are porous or solid, and may or may not have a concentric structure. The most common type consists of granular and finely crystalline pyrolusite in varying proportions, either irregularly mixed or in concentric layers. Those of the latter form are probably derived from kidney ore. They generally contain cavities lined with fine pyrolusite crystals. The ore masses composed of psilomelane may be either solid or porous. The solid masses generally exhibit a concentric structure and have botryoidal surfaces; many of the porous masses have botryoidal forms in cavities. Masses containing both psilomelane and pyrolusite are rare and consist simply of a mixture of the types described above.

3. The breccia ore occurs in residual rock masses, many several feet in extent, embedded in clay. The ore is crystalline or granular pyrolusite and the fragments are mostly sandstone. The pyrolusite is found partly filling cavities between fragments and partly replacing the fragments themselves. Cavities are generally abundant in breccia ore and are lined with fine pyrolusite crystals; many have nodular projections in them.

4. Soft ore is abundant in the Cartersville district, the principal occurrence being at the Dobbins mine. The ore is finely crystalline pyrolusite. It is found in various forms ranging from small seams in sandy clay to large pockets several feet in extent containing small scattered masses of clay. (See fig. 11.) Most of the ore has the consistency of sand, but through this there are scattered fragments of hard ore of the same nature. This ore is plainly a replacement in sandy clay. Many of the pockets are surrounded by a zone of clay, stained and partly replaced by manganese oxides.

DESCRIPTIONS OF MINES AND DEPOSITS.

Location of deposits.—The larger deposits of the Cartersville district (see fig. 8) are in the Chumbler Hill and Moccasin mines east of White; lot 274, the Mayburn mine (lot 303), the Dobbins mine, the Milner-Harris mine, and lots 305 and 306, northeast of Cartersville; lots 460 and 465, east of Cartersville; and the Stegall property near Emerson. Numerous minor deposits occur throughout the district, but very few of them have produced ore. The Cartersville mines have not been operated to any extent for four or five years, so the workings are old and their walls have fallen in.

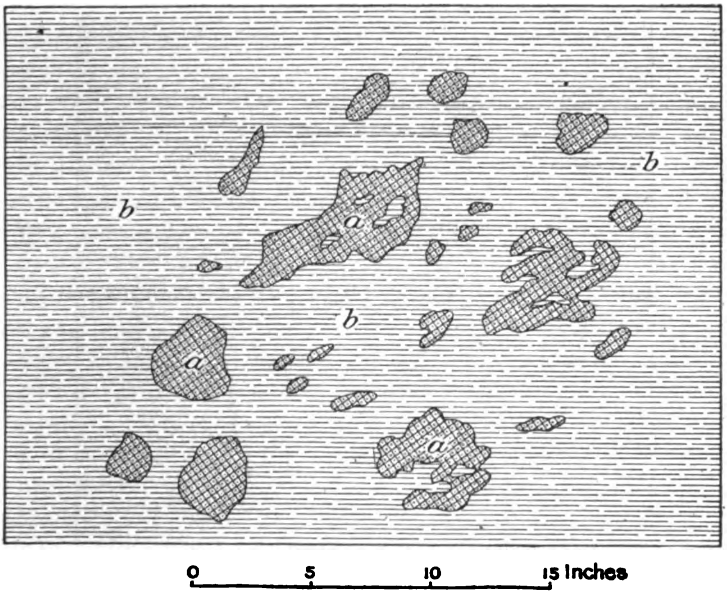

FIGURE 9.—Sketch showing distribution of manganese ore in clay at the Chumbler Hill mine. *a*, Ore; *b*, brown and yellow clay.

Chumbler Hill mine.—The Chumbler Hill mine is about 1½ miles southeast of White, on the northeast slope of a quartzite ridge. The workings consist of a shaft and a large circular open pit about 500 or 600 feet in diameter and over 50 feet deep. The walls of the pit are composed of yellow and brown clays with streaks and masses of white and chocolate clays and a surface layer of dark-red clay. Masses of undecomposed sandstone are still visible in a few places. Here and there stains of manganese appear on the walls as irregular streaks.

The ore occurs embedded locally in the yellow and brown sandy clays as kidneys and larger masses ranging up to a foot in diameter. (See fig. 9.) The lumps have rounded surfaces and many are composed of concentric layers of alternating crystalline and granular pyrolusite and psilomelane. Many are composed entirely of blue granular pyrolusite showing but slight concentric structure. In the clay the ore is soft, but on exposure it hardens.

Moccasin mine.—The Moccasin mine is about one-half mile east of the Chumbler Hill mine, near the foot of the same ridge. The workings consist of a shaft and several small pits in brown clay, in which masses of manganiferous clay and ore occur in a few places. The ore appears to be of the same type as that at Chumbler Hill, but psilomelane is more abundant.

Mayburn mine.—The Mayburn mine, situated about 6 miles northeast of Cartersville, consists of several shafts and small, open pits. The ore is granular and crystalline pyrolusite and it occurs in brown clay as kidneys, seams, and irregular masses. (See fig. 10.) In the clay there are also small fragments of sandstone and pockets of sand. Some of the ore is fairly hard, but much of it is soft and friable. The kidney ore is of two varieties. One variety consists of thin, concentric layers of blue granular and finely crystalline pyrolusite; the other is made up of successive layers of coarse steel-gray needle ore, also pyrolusite. The irregular masses and seams consist of soft ore with fragments of hard ore and many fragments of decomposed yellow sandstone embedded in it. The lumps and

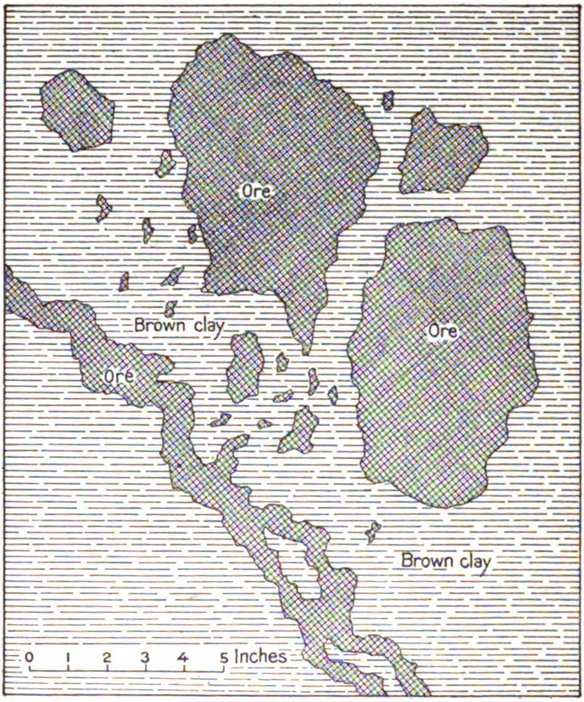

FIGURE 10.—Sketch showing distribution of manganese ore in clay at the Mayburn mine.

pockets vary up to 8 or 10 inches in diameter and are embedded at intervals in the clay. In places they are closely spaced with but a small amount of clay intervening, while elsewhere clay is predominant. Stains of manganese are abundant through the clay, especially around ore bodies.

Lot 274.—Lot 274 is a short distance west of the Mayburn mine. The workings consist of several trenches and small open pits in yellow, brown, and dark manganiferous clay. Little ore is shown in the pits, but on the dumps ores of two varieties were found. The most common type consists of an intricate mixture of crystalline and granular pyrolusite, and occurs in irregular bodies containing cavities lined with small steel-gray pyrolusite crystals. The other type is dense, hard, blue psilomelane with concentric structure. The successive layers in this type are very thin, being rarely over one-tenth inch in diameter, and are separated from each other by much thinner, often scarcely visible laminæ of soft black oxide, probably pyrolusite. Near the surface the ore is very ferruginous and fragments of manganiferous iron ore occur.

Dobbins mine.—Probably the most important mine in the district and the one that was first operated is the Dobbins mine. It is located about 4½ miles northeast of Cartersville and consists of an open pit, a shaft, and numerous trenches, on the south side of a ridge. The deposit has not been worked for many years. The pit is in yellow and brown clays with residual sandstone masses and a surface layer of dark-red clay. Ore is exposed along the walls, and consists chiefly of blue crystalline pyrolusite in a soft, friable form. It occurs in seams and large pockets (fig. 11) through the clay and has somewhat the consistency of sand, though harder lumps are scattered through the soft material. The ore is plainly a replacement in the clay, small masses of clay being still included in the soft-ore pockets. All gradations may be seen from small intersecting seams in clay to large pockets several feet in extent. Manganese ore also occurs in the form of finely crystalline and granular pyrolusite as a cement and replacement in sandstone breccia. The breccia ore contains abundant cavities with botryoidal surfaces, many of which are lined with small pyrolusite crystals.

About half a mile southwest of the principal workings, but still on the Dobbins tract, there are a number of small pits in brown and manganiferous clays. Soft ore with local hard lumps occurs in the manganiferous clay masses.

Milner Harris mine.—The Milner Harris mine is about 1 mile northeast of the Dobbins mine on the same ridge. It consists of old underground workings. No ore was seen in place; that ore on the dumps is similar to the Dobbins ore.

Lot 460.—Lot 460 is about 1 mile east of Cartersville. The workings consist of a number of scattered pits and trenches. Ferruginous manganese and manganiferous iron ores occur as irregular porous masses arranged in bands in brown and yellow clay. These bands in general vary from 1 to 4 or 5 inches in thickness, but masses a foot or more in diameter have been found in them. The manganese ore is ferruginous hard blue psilomelane, or granular pyrolusite.

Lot 465.—Lot 465 is located about 2½ miles east of Cartersville. The workings consist of several open pits in brown, yellow, and red clays. The ore is black or blue granular and finely crystalline pyrolusite and occurs in three different associations: (1) As cement in sandstone breccia; (2) as seams and specks in clay; and (3) as kidneys. The breccia ore is black and consists of a mixture of crystalline and granular pyrolusite cementing and partly replacing brown sandstone fragments. The seams and specks in clay are irregular replacements and consist of black pyrolusite, much of it ferruginous. The kidneys average several inches in diameter and consist of dense blue pyrolusite finely granular and arranged in thin concentric layers.

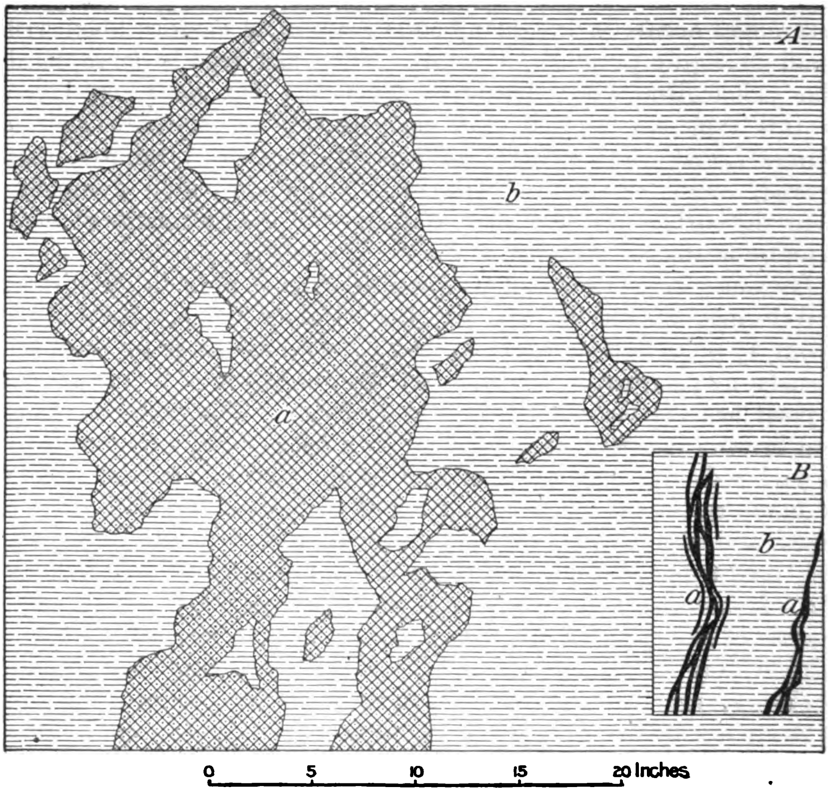

FIGURE 11.—Sketches showing occurrence of manganese ore at the Dobbins mine. *a*, Soft ore; *b*, brown and yellow clay.

ANALYSES.

The following are analyses of manganese ores from the Cartersville district, given by lots or mines:

Analyses of manganese ores from the Cartersville district.[a]

Mine or lot.	Mn.	Fe.	SiO_2.	P.	Moisture.
Lot 614	47.19	10.22		0.28	
Lot 473	37.75		6.05	.222	
Do	35.19		8.95	.206	
Lot 465	47.08	5.60		.194	
Do	43.71		7.10	.236	
Do	46.40		5.25	.277	
Do	44.59		6.82	.144	
Do	48.35		2.60	.122	
Do	39.95		12.92	.198	
Do	47.25		5.60	.198	
Lot 400	39.02		13.50	.245	
Lot 391	46.51	3.30		.055	
Lot 460	40.31		3.76	.127	
Do	41.41		4.50	.134	
Do	15.26	39.25		.193	
Do	48.28			.127	
Lot 260	25.09	29.17		.155	
Lot 306	49.32		3.78	.208	
Do	39.24		14.50	.154	
Do	35.32	3.11		.063	
Lot 303 (Mayburn mine)	54.94	3.62		.034	
Lot 171	24.43	28.21		.322	
Lot 174	47.24			.155	
Do	41.98	16.22		.227	
Chumbler Hill mine	30.32	23.90	6.37	.100	
Do	36.489	15.836	7.56	.089	
Do	40.354	3.286	17.49	.119	
Do	41.430	11.055	7.520	.215	
Do	36.95	10.956	11.37	.167	
Do	27.711	25.250	9.45	.123	
Do	42.933	8.534	12.30	.109	
Do	42.612	4.216	17.37	.106	
Do	41.655	6.292	20.151	.134	
Do	39.226	10.341	14.10	.179	
Do	43.457	4.267	16.45	.103	
Lot 472 (Laramore)	50.83	2.94	7.36	.16	
Do	53.14	1.41	1.35	.074	
Do	47.60	6.50	2.15	.182	
Do	41.28	4.24	10.88	.159	
Do	56.40	1.29	.65	.158	
Do	53.61	1.29	1.13	.154	
Lot 313 (Freeman)	38.00		20.00	.10	
Do	42.40		8.00	.10	
Lot 226 (Smith)	53.20		3.32	.146	
Lots 542 and 543 (Heath)	33.00		32.00	.329	
Lot 504 (Barrow)	47.23	4.85			
Lot 312 (Patillo)	60.61	1.45	2.80	.052	
Milner-Harris mine	52.73	4.49	4.30	.188	
Lot 314 (Stephenson)	38.80		11.45	.160	
Do	40.52		8.42	.169	
Do	34.69		25.90	.108	
Do	37.85		21.37	.134	
Dobbins[b]	52.726	4.49	4.30	.188	
Do.[b]	48.832	5.40	5.05		
Satterfield[b]	44.72	5.19	17.03	.151	9.20

	Lot 391.	Lot 303.
MnO_2	87.60	87.96
Fe_2O_3 and Al_2O_3	9.135	2.520
SiO_2	2.175	8.350
S	.010	.008
P	.065	.120
H_2O and organic matter	1.015	1.042
	100.000	100.000
Mn	54.75	54.975

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[a] Watson, Thomas L., Preliminary report on the manganese deposits of Georgia: Bull. Georgia Geol. Survey No. 14, 1908, pp. 57-65, 67, 68, 71, 76, 77, 83-85, 88, 92, 94.

[b] Weeks, J. D., Mineral Resources U. S. for 1885, pp. 330-331.

CAVE SPRING DISTRICT.

GEOGRAPHY AND TOPOGRAPHY.

The Cave Spring district is situated in northwestern Georgia, near Cave Spring and Cedartown in Floyd and Polk counties. It has a northeast-southwest extent of about 12 miles and a width of about 5 miles. Big Cedar Creek drains most of the area, its waters flowing northward into Etowah River and thence by way of Coosa and Alabama rivers into Mobile Bay.

The topography of the district is one of broad valleys and low ridges, with differences of elevation generally less than 400 feet, though the elevation above sea level ranges from 700 feet in the lower valleys to 2,000 feet on the ridges. The ridge slopes are smooth and rounded. Large areas of comparatively flat country are interspersed with more hilly districts.

GEOLOGY.

The rocks of the district are mainly limestone and shale of Cambrian and Ordovician age. They have the following succession:

- Ordovician:
    - Rockmart slate.
    - Chickamauga limestone.
- Cambro-Ordovician:
    - Knox dolomite.
- Cambrian:
    - Conasauga formation.
    - Rome formation.
    - Beaver limestone.
    - Weisner quartzite.

The Chickamauga limestone constitutes the bed rock in and around Cedartown. It consists of heavy layers of blue limestone and is overlain by the Rockmart slate, consisting principally of black slate with beds of ferruginous sandstone, cherty limestone, and conglomerate in the upper portion. The Chickamauga limestone and Rockmart slate have been removed by erosion between Cedartown and Cave Spring, and northward from Cave Spring, where they appear again, the slate changes gradually to an earthy limestone, and finally to blue limestone with some earthy layers and is included in the Chickamauga limestone.

The Knox dolomite is found underlying a large tract east and south of Cave Spring, and smaller areas to the southwest. It is a massively bedded gray magnesian limestone containing a large amount of silica in the form of chert beds and nodules. The chert beds are in places mixed with or replaced by coarse sandstone. The lower third of the Knox dolomite is supposed to be of Cambrian age and the rest of Ordovician age. The residual material derived from it is of two kinds.

The first consists of dark-red earthy clay derived from the decay of the limestone, and is generally found at the surface. In most places this contains much undecomposed chert in large masses or small fragments, but locally the chert masses are absent. The second variety of residual material consists of stiff light-colored variegated red, brown, and yellow clays such as would result from the decomposition of sandstone or shale. This contains masses of chert and sandstone breccia, and is locally found underneath the first variety. Both varieties of clay contain manganese ore.

Immediately west and north of Cave Spring there is a northeast-southwest belt where the rocks are very much faulted, and hence their surface distribution is irregular. There are several alternating bands of rocks of the Conasauga and Rome formations and some Knox dolomite in this faulted belt, and west of it is a large area of the Conasauga. In its typical phase, as around Dalton, north of this region, the Conasauga consists of a great thickness of clay shales with occasional beds of limestone. In the vicinity of Cave Spring, however, it contains a variety of rocks. At the base are olive clay shales overlain by oolitic limestones, which in turn are overlain by beds of gray crystalline and earthy limestone containing cellular chert. The limestones make up the larger part of the formation.

The Rome formation consists of thin-bedded, fine-grained sandstones and sandy shales of bright variegated colors. The base of the formation is formed by a bed of red sandstone and the top by white sandstones.

The Beaver limestone and Weisner quartzite are exposed in small areas southwest of the manganese area and are lithologically similar to the corresponding formations in the Cartersville district. (See pp. 77–78.)

OCCURRENCE OF THE ORES.

The ores of the Cave Spring district occur (1) as cement in breccia in both dark-red and light-colored, variegated residual clays; (2) as irregular porous masses in dark-red clays; (3) as small pellets in dark-red clays; (4) as kidneys in light-colored variegated clays; and (5) as soft ore in seams and irregular pockets in light-colored, variegated clays. The residual clays are derived largely from the Knox dolomite, but possibly also to a slight extent from the Conasauga formation.

1. The breccia ore cements residual undisintegrated rock fragments. These consist of chert where they occur in the dark-red clay, and of both chert and sandstone in the light-colored variegated clay. The ore is psilomelane and pyrolusite, the former being predominant and having crystals of the latter disseminated through it. It forms varying proportions of the breccia mass, in some places occurring simply as minute seams in solid rock, in others forming the main

bulk with angular fragments of rock embedded in it. (See fig. 12.) It was deposited partly in spaces between the fragments, and partly as a replacement of the fragments themselves. Frequently the original form of the replaced fragments may be distinguished in the ore. As a rule the replacement has gone on only a short distance from the surface, although at times entire fragments have been replaced.

The masses of breccia ore vary greatly in size, many being 5 or 6 feet in extent and even more. A single mass may contain large fragments of solid rock, with only seams and stains of ore, surrounded by material which has been greatly broken up and of which the manganese oxide cement constitutes the larger part.

The breccia ore masses in the variegated clay are largely blue psilomelane, but contain considerable portions of gray crystalline pyrolusite free from fragments. Many of them have botryoidal surfaces and contain cavities lined with smooth nodular forms.

2. Irregular, porous masses are scattered through the dark-red clay in association with breccia ore and pellet ore. Where associated with the former, many of them contain fragments of chert and thus grade into breccia ore. The bodies are generally small, though they vary from a few inches to a foot in diameter. Some are composed of finely crystalline blue or gray pyrolusite, and others of an intimate mixture of the pyrolusite with amorphous dark-blue psilomelane. In this type the psilomelane is commonly on the outside and lines the pores and cavities. The cavities generally have smooth surfaces and are filled with red clay.

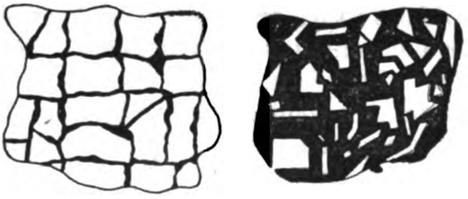

FIG. 12.—Sketches showing structure of breccia ore. (After Watson.) White areas, chert or sandstone; black areas, manganese ore. About one-fifth natural size.

3. The pellet ore is characteristic of only one mine—the Lowe. Here it is found disseminated through dark-red clay (see fig. 15) associated here and there with irregular masses of porous ore, in such a way as to suggest that it might have been derived from the partial disintegration of such masses. However, each individual pellet has a concentric structure, which would lead to the conclusion that each was formed separately, as the nodules of kidney ore were. The pellets are irregularly spherical in shape and have smooth rounded surfaces. They consist of concentric layers which are thinner and more conspicuous near the surface. The pellets are composed largely of black, amorphous psilomelane with gray and blue luster. Through this there appear to be disseminated tiny crystals of pyrolusite.

4. Kidneys of massive blue psilomelane occur in a few localities in the light-colored, variegated clays, associated with sandstone and

chert breccia ore. Some of these show concentric structure; others are altogether structureless. They vary from about 3 to 6 inches in diameter. (See fig. 16.)

5. Pockets and streaks of soft ore occur in the variegated clays on the Sanders property. The pockets are extremely irregular and streaks of ore branch from them into the surrounding clay, while on the other hand bands of clay penetrate the ore in all directions. Dark manganiferous clay generally accompanies and surrounds soft ore pockets, and the contact between the two is very indefinite.

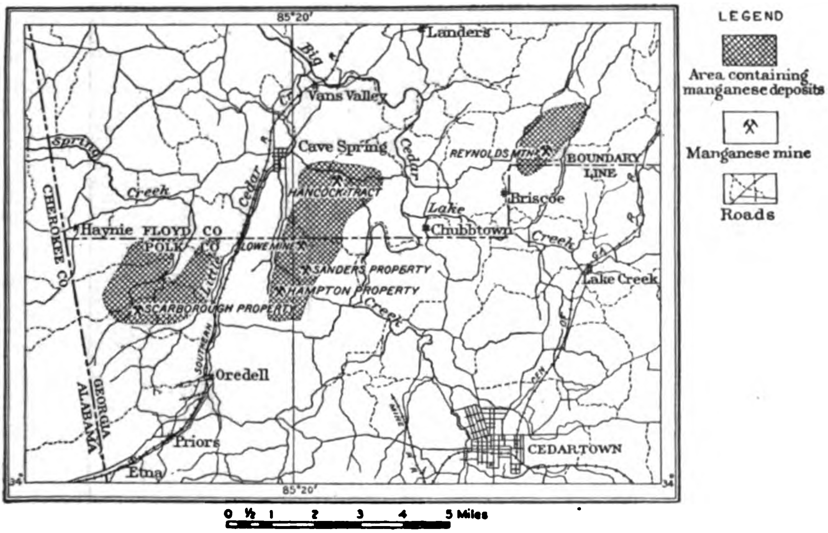

FIGURE 13.—Map showing the principal manganese mines in the Cave Spring district, Georgia, and the probable extent of the ore-bearing areas. (Modified from Watson.)

The ore is soft, powdery, crystalline pyrolusite. The soft-ore pockets commonly contain masses of harder and more thoroughly cemented ore.

DESCRIPTIONS OF MINES AND DEPOSITS.

Location of deposits.—The principal occurrences of manganese ore in the Cave Spring district are at Reynolds Mountain, at the Lowe mine, on the Hampton property, on the Sanders property, and on the Scarborough tract. (See fig. 13.) Deposits of minor importance are found in areas adjoining these. The Cave Spring district has not produced ore for a number of years.

Reynolds Mountain.—The Reynolds Mountain deposit is in Floyd County about 7 miles north of Cedartown and 6 miles east of Cave Spring. Ores are exposed in several open pits in dark-red clay. The ore is of two kinds: (1) Dark-blue psilomelane with a small amount of granular pyrolusite, cementing fragments in chert breccia (fig. 14), and (2) dark-blue finely crystalline and granular pyrolusite in porous masses in clay.

1. The breccia masses vary in size up to 3 or 4 feet in diameter, are of irregular shape, and they are embedded in dark-red clay. They may be composed largely of chert with a few veins of ore filling cracks, or they may consist largely of ore with here and there chert fragments. Between these extremes there are all variations. The ore may be hard or soft, but is most commonly hard. It has botryoidal surfaces in many cavities and contains quartz seams.

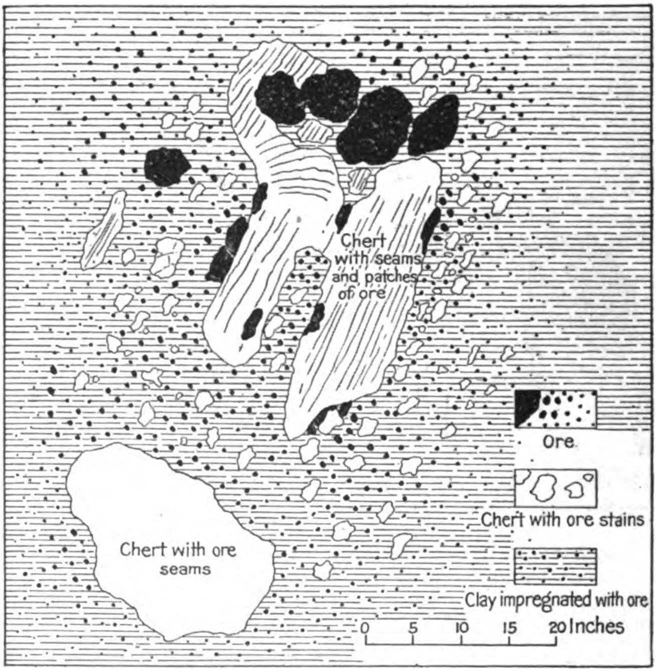

FIGURE 14.—Sketch showing occurrence of breccia ore at Reynolds Mountain.

Ore also replaces the chert fragments, the alteration generally extending but a short distance from the surface, though many small fragments show considerable replacement. The ore is most abundant around the surface of brecciated chert masses between the clay and the more solid interior of the mass.

2. The porous masses of ore are embedded in clay in association with the breccia ore. This porous ore is much softer than the breccia ore and commonly breaks up into little pellets coated with red clay. Scattered masses, however, range up to 8 or 10 inches in diameter and contain numerous pores and cavities filled with red clay. The ore is largely dark-blue or gray crystalline pyrolusite.

Small irregular bodies of yellow ocher occur with the manganese ores.

Lowe mine.—The Lowe mine consists of a large shallow open pit about 2 miles south of Cave Spring. The upper part of the pit is in dark-red clay, 10 to 20 feet thick, and free from chert, while the lower part is in light-colored, variegated clay with chert masses.

The dark-red clay contains ore in two forms, (1) porous masses of mixed blue psilomelane and pyrolusite ranging up to 8 or 10 inches in diameter, and (2) small pellets, largely of psilomelane, averaging less than one-fourth inch in diameter. The latter is by far the most abundant. (See fig. 15.)

The ore in the light-colored clay is largely soft ore and occurs in masses of manganiferous clay. It grades into these masses so that they can hardly be separated. Generally, the ore is in small seams and pockets surrounded by and impregnated with clay, but in some places it is in larger pockets with small seams and masses of clay. A little breccia ore may be associated with it, but as a rule the chert masses contain no ore.

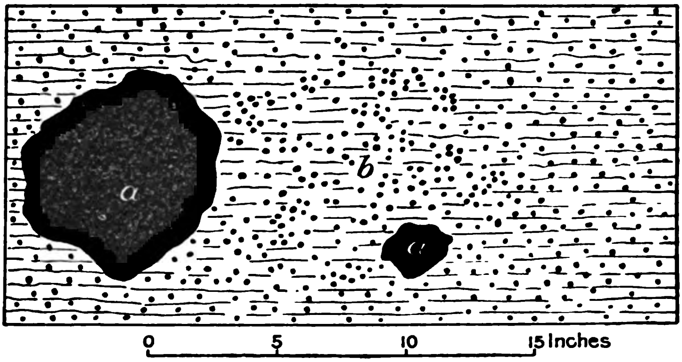

FIGURE 15.—Sketch showing distribution of pellets and irregular masses of ore in clay at the Lowe mine. *a*, Irregular masses of ore; *b*, dark-red clay with pellet ore.

Hampton property.—The Hampton property is in Polk County, a little over 3 miles south of Cave Spring. The workings consist of several open pits in dark-red and brown clay. The ore is largely in chert breccia, though some soft ore occurs in the associated clays.

Sanders property.—The Sanders property is located in Polk County about 2½ miles south of Cave Spring. The workings consist of several open pits and trenches in variegated stiff clay. Both manganese and manganiferous iron ore are found, the latter more abundantly near the surface. The variegated clay contains considerable masses of black manganiferous clay, and here and there irrelar masses of chert are embedded in it.

The manganese ores are soft or hard. The soft ores occur in streaks and pockets in both the light-colored and the manganiferous clays. The bodies are extremely irregular; seams of ore run out into the clay, and stringers of clay run crisscross through the ore. Porous masses of hard ore occur in soft-ore pockets, and these frequently have cavities lined with limonite. Both hard and soft ores are crystalline or granular in texture and consist largely of pyrolusite. The hard ore contains a small amount of psilomelane.

Small nodules or kidneys of hard ore averaging an inch or two in diameter are scattered through the manganiferous clay and soft-ore pockets. Some of them are hard and massive, but others consist of concentric layers of psilomelane and granular pyrolusite, and many of these contain cavities between successive layers, lined with dark-brown amorphous powder. There is little or no breccia ore present, although masses of chert, stained and partly replaced by manganese, occur at intervals.

Scarborough tract.—The Scarborough tract is in Polk County, about 4½ miles southwest of Cave Spring. The workings consist of a pit and shaft.

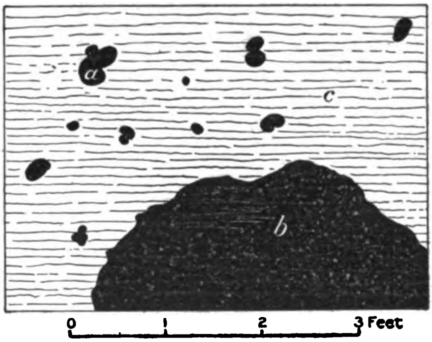

FIGURE 16.—Sketch showing the distribution of manganese ore in clay at the Scarborough mine. *a*, Kidney ore; *b*, breccia ore; *c*, variegated clay.

The ore is embedded in light-colored red, yellow, and brown stiff clays. It is hard and occurs in two forms, (1) as cement in chert and quartzite breccia masses, and (2) as kidneys in clay. (See fig. 16.)

1. Many of the breccia masses are 3 or 4 feet in diameter, and they consist mainly of hard, massive psilomelane containing chert and quartzite fragments. Granular and crystalline pyrolusite is associated with it locally in irregular masses, which are usually free from rock fragments. Many bodies of breccia ore are arranged in bands in the clay, together with masses of crystalline ore and kidneys. Often a layer of botryoidal psilomelane is found partly coating breccia masses, and where cavities occur in such masses they usually exhibit nodular surfaces.

2. The kidney ore is massive bluish-gray psilomelane, with or without concentric structure. The kidneys are hard and are generally fractured, clay penetrating along the cracks.

Other deposits.—Besides the above, there are a large number of smaller deposits in the Cave Spring district, as the Hancock tract, the Youngblood tract, the Lopez property, and others. The ores in them, however, are similar in all respects to those in the mines described.

ANALYSES.

The following are analyses of manganese ores from the Cave Spring district:[a]

Analyses of manganese ores from the Cave Spring district.

	1.	2.	3.	4.	5.	6.
Mn	46.749	42.685	42.938	42.578	42.307	45.189
Fe	1.746	1.729	5.24	1.50	2.40	7.84
SiO_2	13.05	10.00	8.009	11.95	10.39	7.602
P	.059	....	....	.089	.072	9.035

Analysis of high-grade manganese ore from the Cave Spring district.

Mn	53.44
Fe_2O_3	2.83
BaO	8.62
Al_2O_3	1.52
CaO	.080
SiO_2	7.79
P_2O_5	.147
H_2O	1.56
O and undetermined	24.013
	100.00

MINOR DEPOSITS.

PENNSYLVANIA.

Manganese ores are found in the Paleozoic rocks of Pennsylvania. As a rule they occur in small quantities in iron-ore deposits and have been mined to a slight extent in that connection. They occur[b] with the brown ores in the eastern part of the State, at Ironton, Lehigh County; at several places on Broad Mountain, and in Northampton and Berks counties. At the Ironton mines considerable beds of manganese have been encountered. At one place a bed overlies brown iron ore, and at another it is just above limestone and is overlain by brown iron ore but separated from it by a layer of red clay. A bed of manganese ore 2 to 3 feet thick and carrying 50 per cent manganese and 0.4 per cent phosphorus occurs in a red shale in Ground Hog Valley in Broad Top. In the southern part of the State ores occur at Mount Holly Springs, Cumberland County, and at Myers Mills, York County; and in the central part, in Blair, Huntington, and Center counties.

In the Carboniferous region in western Pennsylvania manganese ores[c] are often found with carbonate of iron in small proportions.

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[a] Watson, T. L., op. cit., p. 109.

[b] Weeks, J. D., Mineral Resources U. S. for 1885, p. 342.

[c] Penrose, R. A. F., jr., op. cit., p. 400.

The following is an analysis of manganese ore from Pennsylvania:

Analysis of manganese ore from Ironton, Lehigh County, Pa.[a]

MnO_2	77.96	H_2O	3.98
MnO	4.32	SO_3	Trace.
Fe_2O_3	3.66	P_2O_5	.149
Al_2O_3	.711	SiO_2	4.845
CoO	.39		
NiO	Trace.		100.583
CuO	Trace.		
CaO	.77	Mn	52.631
BaO	.152	Fe	2.562
MgO	.236	P	.063
K_2O	3.042	S	Trace.
Na_2O	.368		

Another analysis[b] of manganese ore from Lehigh County shows 56.58 per cent manganese and a trace of phosphorus. The following are analyses[b] of manganiferous iron ores:

Analyses of manganiferous iron ores from Pennsylvania.

	1.	2.
Mn	17.648	15.934
Fe	26.40	32.400
P	.095	.651
S	.010	.027
Insoluble	21.86	....

1. From Ironton, Lehigh County. 2. From Myers Mill, York County.

MARYLAND.

In Maryland manganese ores have been found in small quantities in the Cambro-Ordovician rocks on Keysers Ridge and Bear Creek, Youghiogheny Valley, Alleghany County;[c] and on the north shore of the Potomac opposite Harpers Ferry.[d]

VIRGINIA.

Besides those in the regions already mentioned (see p. 66) manganese deposits occur elsewhere in western Virginia in association with the Oriskany iron ores.

On Guy Run, about 6 miles south of Goshen, Rockbridge County, is an extensive deposit of manganese ore. The ores are embedded in clays in the form of pockets and occur in close proximity to iron ores of the Oriskany horizon. The following analysis shows the composition of the ore:

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[a] McCreath, A. S., Second Geol. Survey Pennsylvania, 1879, vol. MM, p. 213.

[b] Weeks, J. D., Mineral Resources U. S. for 1885, p. 343.

[c] Ducatel, J. T., and Alexander, H. H., Am. Jour. Sci., 1st ser., vol. 27, 1835, p. 33.

[d] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 416.

Analysis of manganese ore from Guy Run.[a]

Mn	64.59
Fe	3.01
P	.55

Ores have also been reported[a] from Panther Gap and Harts Bottom, Rockbridge County, northwest of Goshen; from Gala and Dagger Springs, Botetourt County; from Gap Mountain, Craig County; from Flat Top, Buckeye, and Spruce River mountains and Sinking Creek furnace in Giles County; from Walker Mountain in Wythe and Pulaski counties; and from Bland, Smyth, and Tazewell counties. All these deposits occur at or near the Oriskany horizon. The ore from Dagger Springs is unique in that it contains numerous fossil bryozoans. The ore at Flat Top Mountain is disseminated through sandstone and is said to contain 59.215 per cent manganese. Manganese ore probably occurring in residual material of the Shenandoah limestone is reported from Middlebrook, Augusta County.

The following analyses show the composition of Craig County ores:[a]

Analyses of Craig County manganese ores.

	1.	2.	3.	4.	5.
Mn	45.00	52.42	49.48	53.06	50.50
Fe			6.83	1.82	4.81
P	.085	.303	.063	.058	.026
S			.010		
SiO_2	4.70	.46	2.53	1.67	.58

WEST VIRGINIA.

Manganese ore is found at Glenmore,[b] Greenbrier County, 7 miles north of White Sulphur Springs, in the same belt as the Oriskany ores of Virginia. It is said to occur as lumps of different sizes embedded in clay and gathered into fairly persistent pockets. It has the following composition:

Analysis of manganese ore from Glenmore.

Mn	50.16
Fe	.20
SiO_2	2.90
P	.084

TENNESSEE.

Manganese ore is reported to exist in pockets along the Chilhowee Mountain range, associated with Cambrian rocks.[c]

Ores occur also in dark-red clay residual from the Knox dolomite at several localities about 2 miles southeast of Morristown,[c] Hamblen

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[a] Weeks, J. D., Mineral Resources U. S. for 1885, pp. 326-327.

[b] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 434.

[c] Penrose, R. A. F., jr., op. cit., p. 416.

County, and with the same associations about 1½ miles northeast of Sweetwater,[a] Monroe County. In the latter locality the ore is mainly in the form of nodules of blue psilomelane, and occurs in connection with iron ores. The following analysis shows the average composition of the ore:

Average analysis of manganese ore from Sweetwater, Tenn.[b]

Mn	45- 55
Fe	3- 8
P	.12-.15

NORTH CAROLINA.

Manganese ores are reported as occurring in Cherokee County,[c] in the southwest corner of the State. They are associated with the iron-ore deposits developed in various Cambrian slates and schists in the vicinity of fault lines. In some places the manganese oxides are so abundant in the iron ore as to make it a manganiferous iron ore.

GEORGIA.[d]

Manganese deposits are associated with residual clays of the Knox dolomite north of Tunnel Hill in Whitfield and Catoosa counties. At this locality a narrow north and south band of Knox dolomite is faulted down into the Rome formation and the ores occur in the dolomite along the east fault. The dolomite is decayed into dark-red and gray cherty clays, the ores being usually found with the dark-red clays. The ore is in the form of kidneys 1 to 12 inches or more in diameter and generally composed of a crystalline interior. The lumps are either scattered or concentrated into pockets. Deposits of limonite and manganiferous iron ore are associated with the manganese ores as pockets and lenticular layers.

The Barnsley tract is in Bartow County 17 miles northwest of Cartersville. Ore occurs here in dark-red residual clays of the Knox dolomite, as honeycombed, porous masses, or as cement in a chert breccia. The cavities in the ore are generally filled with red clay, but many of them are lined with small pyrolusite crystals.

The following analysis shows the composition of the ore:

Analysis of manganese ore from the Barnsley tract.[e]

Mn	43.73
Fe	1.01
SiO_2	3.53
P	.129

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[a] Burchard, E. F., personal communication.

[b] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 424.

[c] Keith, Arthur, Nantahala folio (No. 143), Geol. Atlas U. S., U. S. Geol. Survey, 1907, p. 10.

[d] Watson, Thomas L., op. cit., pp. 128-144, 177-182.

[e] Idem, p. 138.

Ores similar to the above occur near Nannie post-office, Floyd County, 9 miles to the northwest.

In Big Texas Valley, 12 miles northwest of Rome, small quantities of manganese ore occur with iron ores in residual clays derived from Carboniferous rocks. The valley is in a syncline of Carboniferous rocks bounded on the northwest and southeast by ridges of the underlying sandstone of the Clinton (Rockwood) formation.

Indications of manganese are abundant in the area underlain by Knox dolomite in the vicinity of Rome and Lindale, Floyd County. The manganese ores, however, are mainly confined to the surface, passing downward into manganiferous iron and limonite ores. Manganese ore of two types occurs in residual clays of the dolomite, namely, chert breccia ore and kidney ore. In the breccia masses the ore may be present only in small seams and veins, or it may compose the main part of the mass, and contain only small chert fragments. The kidney ore is largely massive and is dark-blue in color. It shows concentric layering.

Surface indications of manganese consisting of small pellets, fragments, and nodules are found near Ligon post-office, Bartow County, 12 miles west of Cartersville. The manganese ores are associated with deposits of iron ore.

Manganese ores have been found in association with iron-ore deposits 4 to 6 miles north of Cohutta Springs, Murray County, in dark-colored, interbedded quartzites and slates of Cambrian age, classed with the Ocoee group. At one locality black crystalline oxide occurs as a cement in quartzite breccia, but constitutes only a small part of it. Elsewhere it is found as nodules in residual clays, or as small pockets in limonite deposits, the latter being the principal occurrence.

In Fannin County, 10 miles northeast of Blue Ridge, nodular or earthy black oxide of manganese occurs in close association with limonite ores. The nodular ore is usually crystalline and occurs as pellets or kidneys in residual clays derived from mica schist, probably of Cambrian age. The ore-bearing clay appears to be in a zone 18 to 20 feet thick and dipping steeply. On one side of it are other residual clays and on the other side a narrow zone of jaspery quartz impregnated with iron and manganese oxides.

Considerable exploitation for manganese ore has been done in the northeastern part of Fannin County, 1½ miles south of Culbertson, N. C., but only a small quantity has been found.

ALABAMA.

Small quantities of manganese ore have been produced intermittently in Alabama, being derived largely from limonite deposits, in which they occurred as pockets, seams, or nodules, commonly forming manganiferous iron ore. The ore is found at the same geologic horizon as the limonites; in fact, the same stratum may contain limonite at one locality and manganese ore at another. Manganese ore also occurs in veins and as cement in breccias in sandstone, quartzite, and chert. It is said to be largely in the form of manganite and pyrolusite.

The manganese ores of Alabama occur in three different associations.[a] In Cleburne County they occur in residual clay near the top of the Wiesner quartzite (Cambrian); in Cherokee County they are found in residual clays of the Knox dolomite (Cambro-Ordovician); while in Blount and Etowah counties they occur near the top and bottom of the Fort Payne chert (Carboniferous).

The ores of Cleburne County are in stratified layers of bowlders and gravels with intermixed sandy loam or in streaks in quartzite bowlders. The principal localities are near Borden Springs.

The deposits of Cherokee County are north and northwest of Piedmont. The ore is in the form of pellets or soft ore in the surface soil or in large masses associated with limonite and bauxite deposits.

The deposits of Blount and Etowah counties are in Murphrees Valley. They are found for a distance of 5 miles along the top and northwest slope of West Red Mountain, but are not continuous, occurring only at intervals along the strike of the rocks. The ore in the lower strata of the Fort Payne chert is in irregular seams and pockets; that in the upper strata is soft powdery ore mixed with surface soil. Bedded layers in the lower strata in a few places reach a thickness of 1 to 3 feet, and bowlders and nodules of very fine ore are associated with them. The deposits in the upper strata also show ore in seams and as hard gravels and small nodules.

The following are analyses of ores from Cleburne County:

Analysis of manganese ore shipped from Stocks Mills, 1886.[b]

Mn	45
Fe	5
P	.8
SiO_2	8

Analysis of manganese ore from Cleburne County.[c]

MnO_2	62.554
Fe_2O_3	9.643
SiO_2	3.670

Manganiferous iron ores have been mined at Woodstock,[d] Bibb County. They occurred in the form of crusts 1 to 3 feet thick overlying the iron ore or in chimneys or pockets in the main deposit. The following are analyses of ores from this locality:

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[a] McCalley, Henry, Alabama Geol. Survey, cited by Birkinbine, John, Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 299; also Smith, E. A., Alabama Geol. Survey, cited by Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 401.

[b] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 401.

[c] Birkinbine, John, Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 299.

[d] Weeks, J. D., Mineral Resources U. S. for 1885, p. 345.

Analyses of ores from Woodstock.[a]

	1.	2.
Mn	11.44	13.68
Fe	38.50	41.76
SiO_2	11.45	24.65
P	.27	.55
H_2O+	11.62	10.66

[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 345.

ORIGIN OF THE ORES OF THE APPALACHIAN REGION.

Several theories have been advanced regarding the origin of the Appalachian manganese ores, but all agree that the source of the ores is in the manganese-bearing silicates originally disseminated through the crystalline and metamorphic rocks of the Piedmont region.

J. D. Dana, followed by Penrose,[a] maintained that the manganese ores were deposited in local basins during the deposition of the rocks in whose residual clays the deposits are now found. The present deposits in the residual clay are supposed to be largely in the same form as the original deposits and to bear the same relation to the clays that the original deposits bore to the inclosing rocks. Penrose points out as evidence of this, in detailed descriptions of numerous deposits,[b] that the ores extend downward from the residual clays into the underlying bed rock, or into residual rock masses in the clay, and are found there in place in the same form in which they occur in the clay. A number of the localities cited by Penrose have been visited by the writer, and so far as he observed the manganese ores in the rock might well be accounted for as depositions from meteoric waters that have percolated downward through the ore deposit in the clay and during their progress have taken manganese into solution. Such ores are generally in the form of veins along joint or bedding planes or irregular replacements in the rock mass.

As corroborative evidence for the theory upheld by Penrose, he points out that the larger number of deposits, especially those of the valley of Virginia, of Tennessee, and of the Cartersville district of Georgia, occur in a fairly definite zone in the Cambrian system, which he has termed the manganese-bearing zone. The rocks of this zone are supposed to have been deposited during a period marked by shallow water and inclosed basins in which manganese and iron were deposited.

As a matter of fact, a large number of deposits are associated with the top of a persistent quartzite bed and the base of the overlying formation, generally a limestone. In Vermont and in the valley of Virginia this quartzite bed is in the lower part of the Cambrian and is as yet unclassified. In the New River region of Virginia and in eastern Tennessee it is the Erwin quartzite; near Cartersville, Ga., it is the Weisner quartzite. The overlying formation is unclassified Cambrian limestone in Vermont, Sherwood limestone in the valley of Virginia, Shady limestone in northeastern Tennessee and southwestern Virginia, and Beaver limestone in Georgia. Overlying the limestone in Georgia, Tennessee, and Virginia there is a thick shale formation, the Conasauga and Rome in Georgia, the Watauga in Tennessee and southwestern Virginia, and the "Buena Vista" in west-central Virginia.

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[a] Penrose, R. A. F., jr., op. cit., pp. 558-559.

[b] Idem, pp. 372-431.

It appears to the writer, however, that the localization is due rather to the impervious nature of the underlying quartzite bed than to original deposition. It seems reasonable that the ores should be deposited by the percolating waters in which they are in solution at the point where the downward course is interrupted by a relatively impervious layer. The same argument has been advanced in a more restricted way for the Cartersville district by Hayes.[a]

The Appalachian manganese ores have not the forms to be expected in residual deposits. It is true that a considerable portion of the ore is in the form of nodular kidneys which might have been present in the original rock in that form, though none have ever been found there. Closely associated with them, however, and far more abundant, are replacement deposits in the form of irregular masses and seams, many occurring along sheared or porous zones in the clay so as to show clearly their secondary origin. Also there are breccia deposits where the ore has been deposited along fault planes or around partly decomposed residual rock fragments in the clay. In these deposits the manganese oxides have largely replaced many of the chert fragments, showing a still later deposition.

The following theory is offered for the origin of the Appalachian manganese deposits: The Cambrian and Ordovician sediments were obtained from the disintegration and decomposition of the crystalline and metamorphic rocks of the Piedmont region. These rocks contained manganese-bearing silicates, such as micas, pyroxenes, amphiboles, and garnets, which were either deposited undecomposed in the shales and to a small extent in the quartzites, or were decomposed and had their manganese content carried in solution and deposited as oxide or carbonate in the shales or limestones. After the sediments emerged from the sea and were consolidated, erosion took place, and during this process the manganese was dissolved, carried downward by percolating waters, and deposited in favorable localities, such as were formed locally by underlying impervious layers or by fault planes. As erosion continued the ores were continually carried downward, being often redissolved and deposited elsewhere,

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[a] Hayes, C. W., Manganese ores of the Cartersville district, Georgia: Bull. U. S. Geol. Survey No. 213, 1903, p. 232; also Hayes, C. W., and Eckel, E. C., Iron ores of the Cartersville district, Georgia: Idem, pp. 233 et seq.

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giving rise to veins and replacement deposits of pyrolusite in sandstone and sandy clay masses and also to breccia ores and other forms.

The manganese in the ores, therefore, may have come from any of the originally overlying formations, but it seems reasonable to assume that a very large proportion of it came from shale formations, for these probably contained a considerable quantity of unaltered manganese-bearing minerals, and, on the whole, a larger percentage of manganese than either limestone or quartzite.

COMMERCIAL IMPORTANCE OF THE ORES.

The manganese deposits of the Appalachian region are the most important in the United States. The two largest producing districts, the Blue Ridge district in Virginia and the Cartersville district in Georgia, are in this region. More than 80 per cent of all the manganese ore mined in the United States was obtained along this belt, but recently work has been carried on only in Virginia and in northeastern Tennessee, the Cartersville and Cave Springs districts of northern Georgia being idle.

The deposits, though not of great size, are numerous; pockets are frequently worked out and abandoned and new ones discovered. In the Crimora basin this is not the case, for here mining has been done for the past twenty years and there is still a large quantity of ore in sight. Structural conditions favored the concentration of the Crimora ore body, and others of this belt are not comparable with it. Single pockets rarely contain more than 25,000 tons, and the majority contain much less. Such discontinuous ore bodies can not be worked on a large scale, and hence the manganese mining industry of the Appalachian region has not made great strides in improvement. Indications of manganese occur abundantly throughout the eastern portion of the Appalachian belt, but workable deposits are found only at intervals. Though considerable prospecting and exploration has been done, it is not at all unlikely that many deposits and perhaps large ones still remain to be discovered.

The ores occur in clay and must have considerable treatment before they are fit for the market. The percentage of clay to ore varies considerably. Locally there may be 1 car of ore to 5 of clay, while elsewhere there may be 1 of ore to 15 or 20 of clay. The ore is crushed, screened, and washed, and then the remaining rock fragments and clay balls are picked out by hand. Frequently the ores are sorted into low-grade and high-grade materials and these are sold separately. In view of these various processes that the ore must go through before it can be marketed, it is not difficult to see why the domestic manganese can not compete with the imported product. The lack of activity does not signify that the deposits are becoming exhausted, for in a number of localities operations have been suspended or are conducted on a small scale where considerable ore is in sight.

The ore of the Appalachian region is a mixture of psilomelane and pyrolusite. As a rule it is of good grade and may be used for chemical purposes as well as in the steel industry. Locally, however, it contains considerable iron, and such ore can only be used in the steel industry. Large deposits of manganiferous iron ore, such as occur at Mine Bank and Blue Bank, near Vesuvius, Va., are lying idle because the manganese content is not high enough to render the ore attractive to producers of spiegeleisen, and too high to render it fit for ordinary pig-iron manufacture. The manganese ores, as well as the manganiferous iron ores, generally contain a large percentage of silica, and many of them are high in phosphorus; hence much of the ore is not desirable for steel manufacture nor for chemical uses.

LOWER MISSISSIPPI VALLEY AND GULF REGION.

Except in the Batesville district, there are only a few manganese deposits in the Mississippi Valley. Of these probably the best known are those of the central Texas crystalline area, of the porphyry area of Pilot Knob, Mo., and of the Silurian or Devonian rocks of west-central Arkansas. Small deposits occur at Whitfield, Tenn., and in eastern Oklahoma.

The deposits are associated with rocks of pre-Cambrian or early Paleozoic age, like all the manganese deposits of the eastern part of the United States. The ores of Missouri and Arkansas are closely associated with iron ores.

BATESVILLE DISTRICT.

GEOGRAPHY AND TOPOGRAPHY.

The Batesville district is situated north of Batesville, in Independence, Izard, and Sharp counties in north-central Arkansas. It extends east and west about 15 miles and north and south about 10 miles. The manganese-bearing area is drained by Polk Bayou on the south and Lafferty Creek on the west, both tributaries of White River, which rises in northwestern Arkansas and flows northward into Missouri and thence southeastward across northern Arkansas. It passes just west and south of the Batesville district and empties into Arkansas River a short distance above the junction of that river with the Mississippi. The area is on the southeast border of the Ozark region, a short distance west of the line dividing that region from the Mississippi flood plain. The topographic contrast between the flood plain and the region around Batesville is very marked. The former is a flat plain with sluggish streams meandering back and forth over it. These are but very slightly below the general level of the country, and in time of floods immense tracts are completely under water. On the other hand, the region around Batesville is hilly and has numerous branching streams, of which the smaller have considerable fall. The difference in elevation is not very great, varying from 250 feet above sea level on the banks of White River to about 800 feet on some of the higher ridges. The larger tributaries are at nearly the same elevation as White River, and the small tributaries drop abruptly from the hills into them. The valleys are narrow and steep sided, many of them being inclosed by bluffs; the uplands are undulating and somewhat more extensive, but are considerably cut up by small streams.

GEOLOGY.

Succession of rocks.—Geologically also there is a great contrast between the Mississippi flood plain and the Batesville district. In the former the bed rock is hidden beneath a great thickness of Pleistocene and Recent fluviatile deposits, while in the latter the bed rock is at or very near the surface and is covered only by a thin mantle of residual material.

The rocks of the Batesville district are Paleozoic, ranging from Ordovician to Carboniferous, as shown in the following table:

General succession of rocks in the Batesville district, Arkansas.

- Pennsylvanian:
  - Winslow formation.
  - Morrow formation.
- Mississippian:
  - Pitkin limestone.
  - {Wedington sandstone member of Fayetteville shale.
  - {Fayetteville shale.
  - Batesville sandstone.
  - Moorefield shale.
  - Boone chert with St. Joe limestone member.
  - Unconformity.
- Devonian (?):
  - Chattanooga shale (?).
    - Sylamore sandstone member (?).
- Silurian:
  - St. Clair limestone
- Ordovician:
  - Cason shale.
  - Polk Bayou limestone.
  - Izard limestone.
  - St. Peter sandstone.
  - Yellville limestone.

There is a general slight southward dip to the beds, so that northward the formations are successively older.

St. Peter sandstone.—The St. Peter sandstone is exposed in the northern part of the manganese-bearing area and along the floors of the larger valleys extending through it. Except the underlying Yellville limestone, which contains the lead and zinc deposits to the northwest, it is the oldest formation exposed in northern Arkansas. It consists of sandstone layers from a few inches to several feet thick. The surface exposures have a peculiar rounded form, and frequently protrude above the soil as knobs and mushroom-shaped masses. The rock is composed of well-rounded white quartz grains, with here and there grains of pyrite, which on the surface are oxidized and give a brown color to the exposures. Cross bedding is characteristic of many parts of the formation. The thickness varies from a few feet to 100 feet or more, the variations being due to different conditions of deposition as well as of erosion.

Izard limestone.—The Izard limestone is found throughout the manganese area, outcropping along the streams above the St. Peter sandstone. It is a grayish-blue, compact, even-bedded limestone, 100 to 150 feet thick in the Batesville area, but reaching, it is said, a thickness of 280 feet at the base of Penters Bluff on White River to the northwest.

Locally in the Batesville district there is 1 to 4 feet of lithographic limestone of a buff color and with conchoidal fracture near the top of the Izard limestone. This generally occurs in two or three layers separated by layers of the ordinary compact limestone. Where this material has been tested it has been found to contain thin seams of calcite that prevent its use for fine grades of work, but there may be localities where large pieces can be obtained in which these veins do not occur.

Along Cave Creek and elsewhere there are numerous caves in the Izard limestone due to solution along fissures. They are not of great size, but extend far back into the hills, being composed of a large number of connected chambers.

Polk Bayou limestone.—The Polk Bayou and St. Clair limestones and the Cason shale were classed by Penrose as one formation and designated the St. Clair limestone. Later Williams separated the St. Clair into the Polk Bayou limestone, Cason shale, and St. Clair limestone. Still more recently Ulrich[a] found an unconformity within the Polk Bayou.

The lower part of the Polk Bayou limestone is of early Trenton age and lies directly on the Izard limestone. It is heavy bedded and coarsely crystalline and has a prevailing white or gray color. Its thickness varies, but probably nowhere exceeds 50 feet. The unconformity above it is marked by a layer of clay from a fraction of an inch to several inches in thickness.

The upper part of the formation, above the unconformity, is thin but very persistent. Like the lower part it is crystalline, but the color is usually a darker gray, and red tints are common and characteristic. Over most of the Batesville district all the formations between the Polk Bayou limestone and the Boone chert are practically absent, being represented only by a few feet of sandstone, shale, and phosphate or manganese bearing formations (Cason shale or Chattanooga shale and Sylamore sandstone member). At such places the surface of the Polk Bayou limestone is generally uneven, with numerous knobs and basins, the former frequently in contact with the overlying Boone chert, and the latter filled with sand, clay, and manganiferous material. The upper part of the Polk Bayou limestone has a persistent thickness of about 15 or 20 feet, so the erosion interval between it and the Cason shale must have been of short duration. The rock is coarsely crystalline and in many parts dark purple, especially near the surface where it is in contact with the manganese deposits.

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[a] Ulrich, E. O., unpublished notes.

Cason shale.—The Cason shale where present rests on the Polk Bayou limestone or the Izard limestone, and is overlain by the St. Clair limestone, or, where this is absent, by the Boone chert. It is the manganese-bearing as well as the phosphate-bearing layer in northern Arkansas. It is varied in character, changing in some parts from point to point so as to be hardly recognizable. The material composing it appears to be largely a residual product derived from a land area not far distant. At several localities where the St. Clair limestone is present, as at the Cason mine, the Cason shale consists of a dark-red sandy shale formation about 10 feet thick with a few thin layers of dark quartzite. The entire formation is heavily impregnated with manganese and iron oxides and the shaly layers contain an abundance of small, flattened, button-like pebbles of manganiferous iron ore, some of which have the appearance of fossil brachiopods. Where the St. Clair limestone is absent and the Cason shale is overlain directly by the Boone chert, as at the Meeker, Southern, Adler, Bales, and other mines, the formation is of an altogether different nature. At the Meeker mine it has a thin layer of green shale at the top. Underneath this is a layer of brown sandstone several feet thick, and underneath that a low-grade manganese formation lying on the uneven surface of the Polk Bayou limestone. (See figs. 17 and 21.) The manganese formation consists of a mixture of manganese and iron oxides with sand and clay. In places one or the other of these beds may be absent, or the entire formation may be disintegrated into a manganese-bearing clay bed, as it is at most of the other mines. Other phases of the Cason shale have been described,[a] but have not been seen by the writer. The following description of the Cason shale is given by Purdue[b] with reference to its occurrence in the phosphate area west of Cushman, where from 8 to 18 feet of St. Clair limestone overlie it:

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[a] Ulrich, E. O., personal communication.

[b] Purdue, A. H., Phosphate deposits of northern Arkansas: Bull. U. S. Geol. Survey No. 315, 1907, p. 466.

> The rocks at the horizon of the Cason shale are of variable nature. It is at this horizon that the phosphate rocks occur. Usually somewhat more than 4 feet at the top consists of shale, or, in the outer part of clay derived from the disintegration of the shale. The upper part of the shale is yellow to brown in color; the lower portion, which ranges in thickness from 2 to 14 inches, is green. In some places the shale contains a thin bed of low-grade iron ore. In other places it is manganiferous. Such samples as were tested were found to be phosphatic, and the rock is probably so everywhere.
>
> The phosphate rocks of the region are associated with this bed of shale. All of the developed phosphates here are below it, but in other places there are phosphatic beds above shale which is presumably the same as this. The phosphate beds vary in character, ranging from those which are brown and sandy and of low grade to those that on fresh surfaces are bluish gray, apparently without sand, and of uniform texture and color. * * *

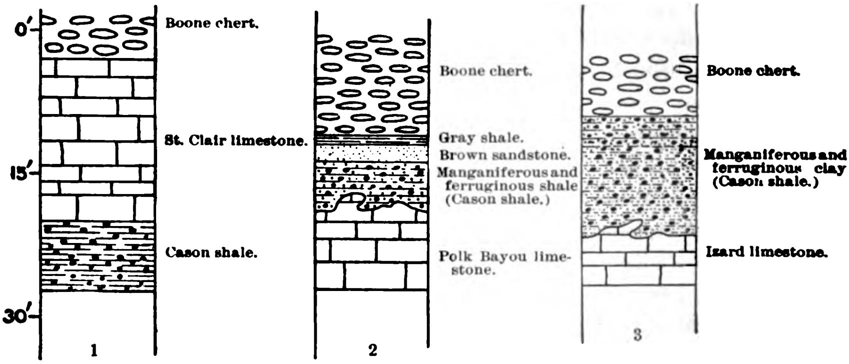

FIGURE 17.—Section showing different phases of the Cason shale. 1, Cason mine; 2, Meeker mine; 3, Southern mine.

> Manganese ore is at many places closely associated with the phosphate bed. So common indeed is the association of the two that débris of manganese, which is plainly perceptible where present, is a good guide in prospecting for phosphate rock.

The different phases of the Cason shale will be described more in detail in connection with the ore deposits.

St. Clair limestone.—The St. Clair limestone is present only in the southern part of the manganese area. The only locality where it was observed was the Cason mine, at which locality it immediately overlies the Cason shale, here composed of abundant ferruginous manganese ore pebbles embedded in a red sandy shale formation. The thickness of the St. Clair limestone in this vicinity is given by Penrose [a] as 100 feet. It rapidly thins out and disappears to the north.

In the phosphate area on East Lafferty Creek, west of Cushman, 8 to 18 feet of St. Clair limestone is said [b] to be exposed over the Cason shale. Throughout the main manganese area, however, the Boone chert lies directly on the Cason shale, or the manganese-bearing clay equivalent to it, and the St. Clair limestone is absent.

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[a] Penrose, R. A. F., jr., op. cit., p. 220.

[b] Purdue, A. H., op. cit., p. 463.

The St. Clair is a pink or gray crystalline limestone with an abundance of fossils consisting mainly of crinoid stems and brachiopods. It was deposited in narrow embayments, and its irregular distribution and thickness are due to this rather than to subsequent erosion, as is shown by the fact that its upper beds are more widely distributed than its lower ones.

Chattanooga shale.—The Chattanooga shale was not positively recognized in the Batesville district. There is a possibility, however, that where the St. Clair limestone is absent the green shale and brown sandstone layers at the top of the Cason shale, as seen at the Meeker mine, may be equivalent to it. The Chattanooga shale with its basal Sylamore sandstone member is, however, well developed in the lead and zinc district to the northwest. There it lies on the eroded surface of any of the preceding Silurian or Ordovician formations down to the Yellville limestone. As a rule it is followed directly by the St. Joe limestone member of the Boone chert. The greatest thickness of the Chattanooga in Arkansas probably does not exceed 50 feet, the Sylamore sandstone member making up considerably more than half of this thickness. In most exposures the thickness of the Chattanooga is under rather than over 10 feet. The sandstone member is composed of coarse rounded quartz grains. The rock reminds one strongly of the St. Peter sandstone, but is readily distinguished by the presence of small phosphatized pebbles. At many points it thins out and disappears, or is present only in lenses in the shale. Where best developed the shale is black and fissile. A bed of greenish clay shale, 2 to 12 inches thick, is commonly found at the top.

Boone chert.—The Boone chert in Arkansas usually begins with the St. Joe limestone member, which is easily distinguished from the overlying beds of the formation by the even-bedded, coarsely crystalline, noncherty character of its ledges, and also by the reddish color of some of its beds. The St. Joe member does not occur generally in the manganese district, but locally a few feet of pure limestone at the base of the Boone are believed to represent it.[a] In the lead and zinc district the formation reaches a thickness of 30 feet.

The Boone chert above the St. Joe limestone member is characteristically developed in the Batesville district, where it occupies the tops of the ridges and all high areas. It is supposed to be over 300 feet thick, but the top is not exposed in this district. The formation consists of a very cherty limestone, some of the beds being almost entirely chert. It is generally light-gray in color and even-bedded. It overlies the manganese-bearing formation and is present above most of the deposits. At some places it is horizontal and at others folded and crenulated, apparently on account of the slumping of the underlying clays.

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[a] Purdue, A. H., op. cit., p. 467.

OCCURRENCE OF THE ORES.

GENERAL RELATIONS.

Ores of the Batesville district occur in three different associations, but all of them are at very nearly the same stratigraphic horizon. (1) The principal deposits (see fig. 18) occur in the manganiferous portions of the Cason shale between the Polk Bayou or the Izard limestone and the Boone chert. In places the lower part of this formation consists of a solid bed of low-grade ore, while elsewhere masses of manganese ore are scattered through an ocherous and manganiferous clay shale formation, probably derived from the disintegration of the ore bed. The Cason shale is manganiferous over a large area north and northwest of Batesville. In some parts only stains and thin layers of manganese oxide occur, while elsewhere there are large deposits of ore. As the Boone chert in general caps the ridges, these deposits, occurring under it, outcrop on the hillsides. For the most part the formation where extensive consists of manganiferous and ferruginous clays containing scattered masses of ore, but in a few places it is still consolidated and consists of layers of shale, sandstone, and sandy ferruginous manganese ore. The last contains local masses of pure ore. (2) Numerous deposits of ore occur in clay on the hill slopes below the main manganese-bearing layer, or in places where that layer has been entirely eroded away. The ore occurs in irregular masses in dark-colored clays which lie on the eroded surface of the lower rock formations, where they have accumulated to a thickness varying from a few feet to 20 feet or more. The ore is derived by

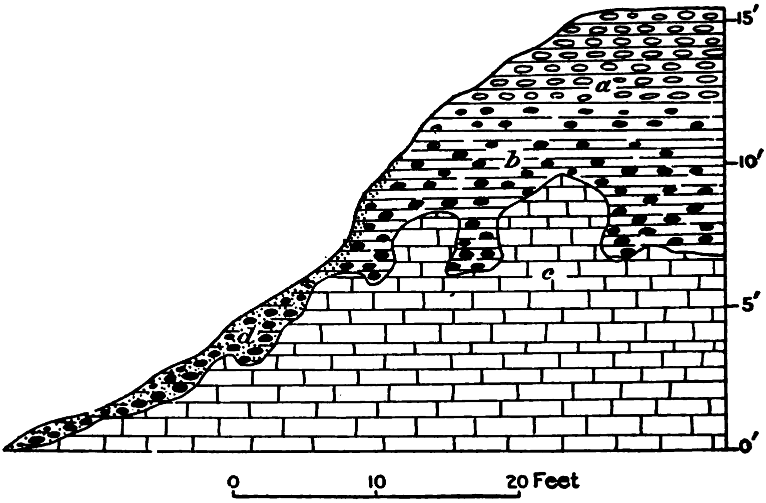

FIGURE 18.—Generalized section showing the occurrence of the Batesville manganese ores. *a*, Boone chert; *b*, Cason shale with manganese deposits; *c*, Polk Bayou limestone; *d*, surface clay with manganese deposits.

concentration, partly mechanical, partly chemical, from the manganese-bearing bed above where that bed is rich in ore. (3) In the southern part of the district there is a bed of low-grade manganiferous iron ore beneath the St. Clair limestone which is present here under the Boone chert. This class of deposit consists of small, flattened, button-like pebbles of manganiferous iron ore arranged along planes of stratification in a dark-red sandy shale. The shale is overlain by the St. Clair limestone and is presumably equivalent to the Cason shale, although its associations and structure are very different from those of the Cason shale over the rest of the area. It is more fully described in connection with the Cason mine.

FORMS OF THE ORES.

The ore masses in the first two classes of deposits are irregular and of various sizes. Similar types of minerals are found in both, but there is a difference in their relative abundance. Each fragment generally consists of but one mineral, although sometimes several different minerals are found in the same mass. The following are the principal forms in which the ore occurs:

(*a*) Fragments of hard massive blue psilomelane form the most abundant ore in both original and concentration deposits. They generally contain small irregular cavities filled with calcite or clay, or lined with small crystals or black powder of manganese oxide.

(*b*) Next in importance are fragments of coarsely crystalline brownish or steel-gray braunite. These are very heavy and have a solid interior, but many of them are somewhat porous near the surface. They are much more abundant in the concentration deposits than in the original bed. Veins of braunite occur in many masses of psilomelane, showing that in these masses it is formed later than the psilomelane, and suggesting that a part of it may have been deposited during the reconcentration.

(*c*) Another type of ore which is more abundant in the concentration deposits is a blue, finely crystalline, pumaceous ore. Some fragments composed of this ore are very hard, while others are soft and friable; but all contain numerous small pores and cavities.

(*d*) Chert breccia ore in large masses occurs in the concentration deposit at the Roach mine. It is composed of fragments of white chert cemented by amorphous soft oxide of manganese.

(*e*) Kidney ore of massive blue psilomelane is found in the same locality as the breccia ore.

Besides these types, there occur masses of soft ore replacing limestone or clay and powdery manganese oxide in cavities in other ore masses.

The manganese ore buttons occurring in the third class of deposit—that is, in the manganiferous iron ore bed—consist largely of psilomelane.

DESCRIPTIONS OF MINES AND DEPOSITS.

Cason mine.—The Cason mine is about 3½ miles north-northeast of Batesville. (See fig. 19.) The workings consist of two quarries in solid rock on a hillside. In these are exposed 10 to 15 feet of horizontally bedded dark reddish-chocolate sandy shale (the Cason shale) overlain by gray fossiliferous crystalline limestone (the St. Clair limestone), which is exposed on the slope above the pits. Immediately above the shale the limestone is thin-bedded and contains particles of manganese oxide, which are especially abundant around fossils. The shale is interbedded with several thin layers of darkly stained quartzite. The base of the formation is not to be seen, so it is impossible to say what the underlying rock is.

The ore is manganiferous iron ore. It occurs as small buttons or lenses, one-half to 2 inches in the longer diameter, and one-fourth to one-half inch thick, lying along planes of stratification in the shale layers. They are closely grouped and generally make up more than half the mass of the rock. Many of them have forms very similar to fossil brachiopods but none could be definitely determined. Where very closely spaced, they form thin horizontal layers.

The lower portion of the bed contains fewer buttons and more barren layers. These may be hard and quartzitic, or soft and friable, and are darkly stained and partly replaced by manganese and iron oxides. Both barren and ore-bearing layers are soft and decomposed at the surface.

O'Flinn mine.—The O'Flinn mine is about 5½ miles north-northeast of Batesville. The workings consist of an old shaft. Surface exposures of the Cason shale at this locality show buttons of manganiferous iron ore in dark and sandy shale, similar in occurrence to the ore at the Cason mine.

Trent mine.—The Trent mine is about 1 mile west of the O'Flinn mine. The workings consist of old trenches in dark-brown and black clays, in which occur a few horses of darkly stained Polk Bayou limestone. The ore is scattered through the clay in irregular flattened fragments, varying in size up to 8 or 10 inches in the longer diameter. They are concentrations from the manganese-bearing layer on the hill slope above. As a rule the fragments are dull-black and porous near the surface and have a solid shiny interior, but the reverse may be true, and in that case they have irregular elongated cavities in the interior containing dark clay. Some of the fragments consist of steel-gray or brownish coarsely crystalline braunite, while others are amorphous and consist of dark-blue and gray psilomelane. Still other fragments are composed of a mixture of crystalline and amorphous ore.

Reeves mine.—The Reeves mine is about one-half mile north of the O'Flinn mine and consists of a cut on a hillside. The bank is composed of horizontally banded yellow, red, and brown clays above and umberous manganiferous clay below. The latter is seamed with red and brown clay. The ore occurs in the manganiferous clay in irregular fragments of two kinds—(1) solid masses with a shiny interior, such as those of the Trent mine, and (2) blue, friable, pumaceous masses. The first are generally amorphous and hard; the second are finely crystalline.

Adler mine.—The Adler mine is about three-fourths mile north of Reeves mine. The workings consist of a number of old pits scattered over a hillside. In some of these the manganese-bearing layer was mined and in others the concentration deposits on the slopes below were mined. Ore is visible only on the dumps and appears to be of the pumaceous crystalline variety found at the Reeves mine. In the pits that enter the ore layer the Boone chert is exposed in the upper part, and underneath it is a thin shale layer, which overlies several feet of manganese-bearing clay. In the lower part of the pits the Polk Bayou limestone is exposed as horses extending upward into the clay. The limestone horses are stained with specks and veins of manganese.

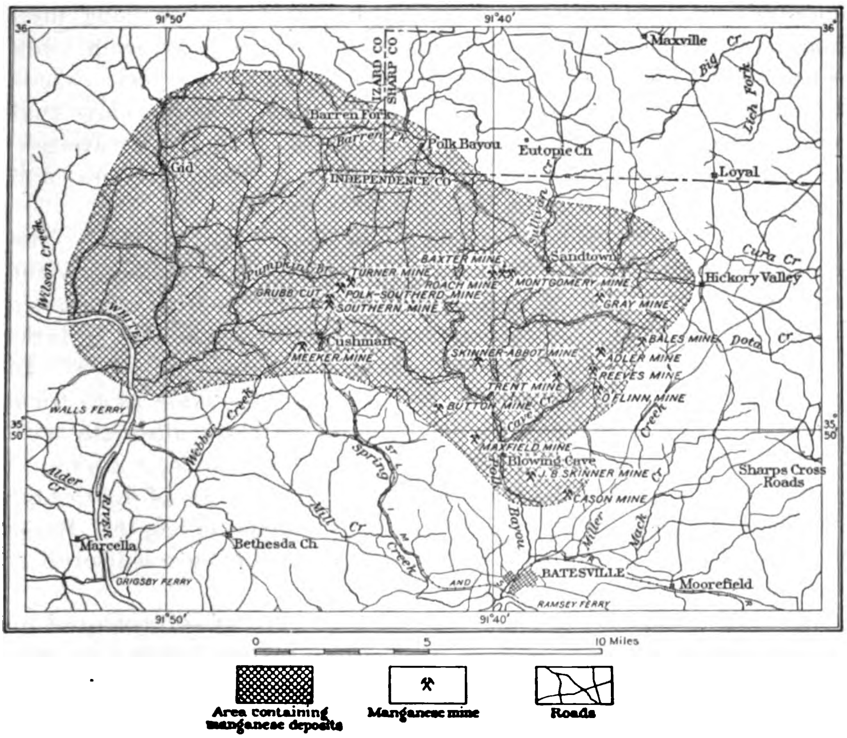

FIGURE 19.—Map showing the principal manganese mines in the Batesville district, Arkansas, and the probable extent of the ore-bearing area. (Modified from Penrose.)

Bales mine.—The Bales mine is 2 miles northeast of the Reeves mine. It consists of two sets of workings about one-fourth mile apart. One consists of a number of trenches, the other of a tunnel with shaft connection and several pits. Both workings are on the main ore-bearing layer above the Polk Bayou limestone. The ore is dark-blue, friable, and largely amorphous, and occurs in masses in umberous manganiferous clays, and as local replacements in the underlying limestone.

Skinner-Abbot mine.—The Skinner-Abbot mine is about 7 miles north-northwest of Batesville. The Izard limestone is here exposed abundantly at the surface. It has gone into solution along joint planes and formed openings with rounded vertical walls, from a few feet to 10 or 15 feet wide and ranging in length up to 100 feet. These openings contain black soil and brown and manganiferous clays that carry fragments of manganese ore. The ore is of three varieties: (1) Coarsely crystalline gray ore; (2) hard blue massive ore; and (3) hard blue porous finely crystalline ore.

Roach mine.—The Roach mine is 9 miles north of Batesville. The workings consist of several trenches in clay, on a hill lying in a syncline of the St. Peter sandstone. No limestone is visible, but an abundance of chert fragments are scattered over the surface. The clay is dark-brown or chocolate colored and darkly stained by manganese. In some places it is so impregnated with manganese oxide as to form solid bodies of low-grade ore. Manganiferous clays alternate with masses of chocolate clays, and large bodies of chert breccia are found with both. The chocolate clays contain kidney ore of hard blue massive psilomelane in irregular lumps 3 to 6 inches in length. Some of these are very closely packed together, and others are scattered at considerable intervals through the clay.

The chert breccia consists of fragments of white chert cemented by a black amorphous manganese oxide that predominates over the chert. It occurs in large masses, some of them 4 or 5 feet in extent. The fragments of chert are generally small and considerable ore is found in the breccia masses in which there is little or no chert. Where cavities occur in the breccia ore they are lined with nodular projections. Much of the kidney ore contains chert fragments and thus grades into breccia ore.

Baxter mine.—The Baxter mine, about one-half mile east of the Roach mine, consists of a large open cut. The walls are composed of reddish-chocolate clays below and lighter-colored clays with chert fragments near the surface. In the chocolate-colored clays are masses of dark-red decomposed shale and limestone. The ore is of a similar type to that in the Montgomery mine described below. Both the Baxter and the Montgomery cuts contain near their mouths large masses of a limestone-marble breccia. These are composed of a mixture of massive limestone like the Izard, and crystalline limestone like the lower part of the Polk Bayou.

Montgomery mine.—The Montgomery mine adjoins the Baxter on the east and likewise consists of a large open cut. On the walls are exposed reddish-chocolate clays with large masses of dark-red decomposed limestone and shale, still showing original textures.

The ore is of two kinds—pumaceous, finely crystalline ore and button-like, pebbly ore. The former occurs in thin parallel layers through the clay, as though it were a replacement of certain layers of rock. (See fig. 20.) Successive layers are varying distances apart and between them are residual clays. The button ore occurs in the clays as well as in the ore layers. It consists of small flattened and spherical pebbles, the former very much like those in the Cason mine. The flattened pebbles are seldom more than 1½ inches in the longer diameter, and one-third inch thick, and the spherical pebbles are still smaller. The former lie with their longer diameters in the same plane, this probably being the plane of stratification of the original rock. Both types are dark blue. The button-like concretions are dense and hard; the ore layers, though hard, are porous.

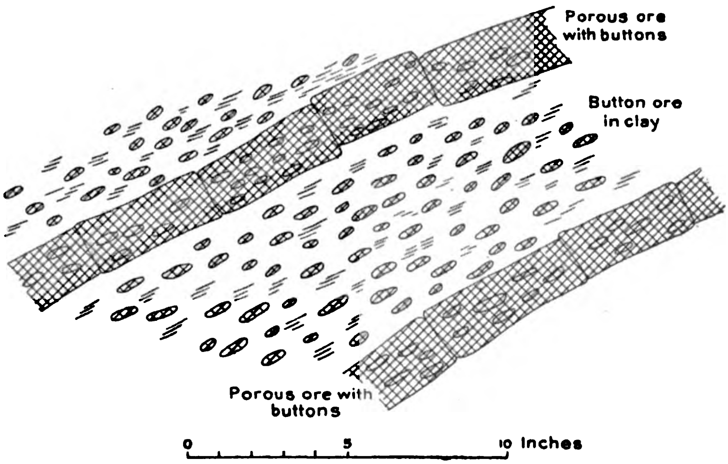

FIGURE 20.—Sketch showing the occurrence of manganese ores at the Montgomery mine.

Meeker mine.—The Meeker mine is about one-half mile west of Cushman. The workings consist of several open cuts and tunnels, mostly recent, on the manganese-bearing layer between the Polk Bayou limestone and the Boone chert. The surface of the former is very uneven, as in other places mentioned, and horses of it extend upward into the manganese-bearing layer. This varies from a few inches to 10 feet thick, depending on the size of the limestone horses. It is composed of the following succession of layers (fig. 21):

Boone chert.
Manganiferous clay 2 to 3 inches thick.
Green shale varying in thickness up to a foot or more. Absent in places.
Brown sandstone 2 to 3 feet thick.
Sandy manganese and iron oxide formation varying in thickness up to 6 feet or more. Locally the lower foot or two is hard and siliceous, while elsewhere there are 6 inches or a foot of manganiferous clay at the base.
Polk Bayou limestone.

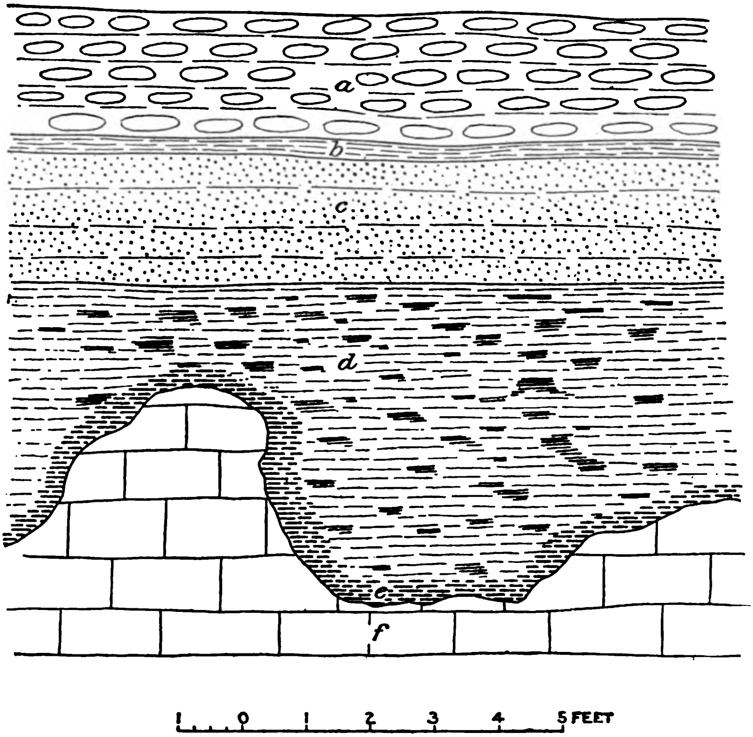

FIGURE 21.—Sketch showing the occurrence of manganese ores at the Meeker mine. *a*, Boone chert; *b*, green shale or manganiferous clay; *c*, brown sandstone; *d*, manganese-bearing ferruginous shale; *e*, manganiferous clay or dark indurated siliceous layer; *f*, Polk Bayou limestone.

The manganese-bearing layer consists of thin horizontal layers of manganese and iron oxides, mainly the former, interlaminated with yellow and red sandy material. The layers are generally crenulated and are one-sixteenth to one-half inch thick. The variations are generally abrupt and sharp, causing great irregularity. Locally large porous masses of manganese ore 4 or 5 inches thick are embedded in the low-grade laminated ore. They consist of dark-blue massive psilomelane, with a small amount of finely crystalline material in cavities. Many of the cavities are entirely or partly filled with calcite.

Southern mine.—The Southern mine is about 1 mile north-northeast of Cushman. It consists of two large open cuts and many shafts.

The Boone chert is exposed in the upper part of the cuts and beneath it are 10 to 15 feet of ocherous, manganiferous, red and brown clays, in which occur the ores. Many of the shafts go through 20 to 40 feet of chert into the underlying ore-bearing layer. The ore was not seen in place at the Southern mine.

Grubb cut.—The Grubb cut is several hundred yards northeast of the Southern mine. The workings consist of an old open cut with a recent shaft in the floor. The walls of the cut consist of Boone chert in the upper part with 10 to 15 feet of manganese-bearing clay below it. In the bottom there are horses of coarsely crystalline Polk Bayou limestone. The beds of chert are considerably folded as a result of slumping in the underlying clays. The ore recently taken from the shaft is of a hard blue porous variety of psilomelane, with some red ore which is presumably stained by iron.

Polk-Southerd mine.—The Polk-Southerd mine is about 2 miles northeast of Cushman and consists of an old cut and several old shafts. The chert forms the upper part of the walls of the cut, but the ore-bearing layer below it is covered with débris. Pieces of ore on the dump are of a porous blue variety of psilomelane.

Turner mine.—The Turner mine consists of an old open cut and several shafts about half a mile northeast of the Polk-Southerd mine. In the bottom of the cut there are horses of massive blue Izard limestone with associated green shale. The manganese-bearing clay, which is reddish brown, lies directly on the Izard limestone, and is overlain by the Boone chert locally. The ore, consisting of massive blue psilomelane and gray crystalline braunite, is found in fragments in the clay.

Many other old mines are present in different parts of the district, but those described show fully the different forms and associations in which the ores occur.

ANALYSES.

The following are analyses of psilomelane and braunite from the Batesville region:

Analyses of psilomelane from the Batesville region.[a]

	1.	2.	3.
MnO	77.85	84.995	82.448
O	14.56	10.483	10.002
Fe_2O_3	.90	....	....
Al_2O_3	.80	....	....
CaO	1.81	Trace.	1.178
BaO	.21	.512	.282
MgO	Trace.	....	Trace.
K_2O	1.99	....	....
Na_2O	.97	....	....
P_2O_5	.67	....	....
H_2O	....	1.820	.611
SiO_2	.83	2.845	5.329
	100.59	100.655	99.850

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[a] Penrose, R. A. F., jr., Manganese: Its use, ores, and deposits: Ann. Rept. Arkansas Geol. Survey for 1890, vol. 1, 1893, pp. 145, 147.

Analyses of braunite from the Batesville region.[a]

	1.	2.
MnO	87.47	75.386
O	9.62	7.979
Fe_2O_3	.44	3.523
Al_2O_3	.11	....
CaO	.34	1.833
BaO	.48	....
MgO	Trace.	.192
K_2O	.10	....
Na_2O	.05	....
P_2O_5	.25	....
CoO	....	Trace.
H_2O	....	1.295
SiO_2	.18	9.968
	99.04	100.176

[a] Penrose, R. A. F., jr., op. cit., pp. 148–149.

The following are analyses of manganese ores of the Batesville district, given by mines:

Analyses of manganese ores of the Batesville district.[a]

Name of mine.	Mn.	Fe.	SiO_2.	P.	Moisture.
Cason	34.64	4.88	25.65	0.58	....
Do	50.41	7.56	12.67	.06	....
J. B. Skinner	38.30	8.45	....	.38	....
Do	39.35	5.30	....	.217	....
Maxfield	44.69	9.18	3.23	.319	....
Do	41.08	10.75	....	.467	....
Do	43.12	12.50	1.54	.339	....
Do	42.74	4.95	10.41	.385	....
Do	31.90	11.20	20.50	.347	....
Do	24.31	21.63	14.82	.252	....
Do	24.50	28.72	5.22	.226	....
Do	27.49	23.40	7.08	.405	....
Do	29.57	23.40	5.10	.452	19.00
Do	31.56	21.47	6.75	.385	16.40
Do	26.82	24.42	7.33	.273	16.20
Do	27.55	24.00	7.46	.268	15.50
Do	30.55	21.70	6.48	.328	15.00
Do	33.21	18.80	6.05	.194	15.10
Do	31.35	20.70	4.49	.581	14.50
Do	37.59	12.70	5.56	.357	18.20
Do	34.38	17.70	4.03	.476	21.50
Do	36.05	15.50	4.87	.279	18.30
Do	37.27	15.30	4.55	.481	21.10
Do	28.69	23.00	5.42	.788	20.00
Do	33.80	16.85	5.70	.569	19.10
Do	34.03	11.20	3.65	.732	16.30
Do	36.88	14.70	3.97	.608	18.50
Do	35.40	15.70	4.35	.735	16.30
Do	36.86	15.20	3.68	.585	12.00
Castile	55.45	2.95	5.60	.117	1.30
Do	57.13	1.89	5.39	.078	1.30
Gray	50.81	2.90	2.50	.126	....
Do	46.36	8.53	4.25	.128	2.50
Do	49.36	5.97	3.90	.156	5.50
Skinner Abbot	55.68	2.00	....	.172	....
Do	53.60	2.50	....	.209	....
Do	51.86	7.80	....	.141	....
Do	42.77	5.50	....	.523	....
Do	56.10	2.61	5.44	.075	.60
Do	57.01	2.05	5.33	.072	.80
Do	57.41	1.62	6.00	.100	1.00
Do	55.70	1.85	6.71	.078	.80
Do	56.75	2.19	5.49	.068	.20
Do	57.39	1.55	5.46	.074	.10
Do	38.49	8.80	19.96	.115	7.00
Do	56.65	1.68	5.55	.066	.80
Do	58.31	1.33	5.78	.064	.90
Baxter	55.60	8.78	24.58	.149	9.80
Do	47.70	4.77	10.98	.284	9.20
Do	45.77	4.67	14.06	.342	8.20
Southern	53.12	2.30	2.75	.165	4.40
Do	51.82	3.40	2.50	.193	5.10
Do	50.75	4.27	3.52	.184	5.40
Do	49.73	2.15	3.10	.166	7.28
Do	51.77	2.38	3.18	.128	1.68
Do	49.60	3.84	4.79	.184	3.88

[a] Penrose, R. A. F., jr., op. cit., pp. 219, 221, 224, 227, 238, 242, 245, 262.

ORIGIN OF THE ORES.

Penrose, in his study of the Batesville manganese deposits, developed the theory that the ores were deposited from solution in local basins at the same time that the rocks associated with them were deposited.[a] The materials he supposed to have been derived from the crystalline land mass in southeastern Missouri, or from a similar one farther south, the ancient porphyries of this region being known to carry manganese. The St. Clair limestone is given as the formation with which the ores were originally laid down. Penrose did not distinguish the Polk Bayou limestone and Cason shale as separate formations from the St. Clair limestone, as they have been shown to be by the work of Ulrich and others, and supposed the manganese to be interlayered with the St. Clair at different horizons[b] instead of being at a definite horizon in the Cason shale. The varying thicknesses of the several limestone formations he accounted for by nondeposition rather than by intervening erosion periods, apparently supposing the limestones and the Boone chert to have been laid down during a continuous period of deposition. Shallow water and lagoons developed locally at times, and there manganese was deposited as carbonate or oxide, either in local deposits or in a disseminated state through the rocks. The disseminated material was later concentrated into nodules and masses, such as are seen in the Cason mine.

The present ore deposits Penrose supposed to have been derived from the Polk Bayou limestone (designated by him the lower part of the St. Clair), by its decay, the ores accumulating in siliceous and ocherous material on its surface, while the calcium carbonate was carried off in solution. This decay he supposed to take place underneath the Boone chert, the waters coming downward through fractures in that formation and attacking the underlying limestone; as evidence for that process he points to the local slumping of the chert. This decay produced the uneven surface of the limestone underlying the ore-bearing material.

In the light of later developments it will be necessary to alter this hypothesis considerably. As far as the original source of the manganese and the accompanying sediments is concerned, the hypothesis still holds good. The Izard and Polk Bayou limestones were laid down over wide areas, and between the two periods of deposition there was an intervening period of erosion. While these limestones were being deposited the St. Francis Mountains in southeastern Missouri were being disintegrated and a heavy mantle of residual material formed. When the Polk Bayou had been deposited there was another slight period of erosion, after which the area was again submerged and the residual material which had been gathered on the St. Francis Mountains land mass to the north was deposited over it, on the uneven surface of the Polk Bayou limestone or lower formations where this had been removed. This material formed the Cason shale. Manganese and iron oxides, mainly the former, became concentrated locally in this layer and phosphatic[a] material became widely distributed through it. The manganese and iron oxides were brought in from the granite and porphyry areas in the land mass to the north, probably in solution, and were deposited with the residual material where conditions were favorable.

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[a] Penrose, R. A. F., jr., op. cit., pp. 586 et seq.

[b] Idem, pp. 174 et seq.

After the formation of the Cason shale local warping took place, resulting in the formation of deep embayments separated by shallow areas or even by land masses.[b] The St. Clair limestone was deposited on the Cason shale in the embayments, while elsewhere no deposition took place. However, in the areas between these embayments a reconcentration of the manganese and iron oxides took place, as is shown by the fact that only where the St. Clair limestone is absent are there workable deposits. Where it is present the Cason shale contains only low-grade deposits and stains of manganese, as at the Cason mine and at localities mentioned by Purdue[c] with reference to the phosphate rocks of this bed.

After the restricted deposition of the St. Clair limestone came the deposition of the Boone chert over a wide area, probably preceded locally by the deposition of the Chattanooga shale. Subsequent erosion has resulted in a concentration, partly mechanical and partly chemical, of the ores in the ore-bearing layer and in the residual clays on the hill slopes below it. The ores are therefore original depositions reconcentrated during two subsequent land stages—first, during late Silurian and Devonian partial emergence, and second, during the post-Paleozoic erosion of the Boone chert.

It is questionable on which concentration most stress should be laid, but from the universal presence of manganese above the Polk Bayou and Izard limestones, it seems likely that most of the materials were gathered during the original deposition. Local concentration into ore bodies, however, did not take place until long after the deposition of the St. Clair limestone.

That the ores were not derived to any extent from the underlying Polk Bayou limestone, as Penrose suggested, is shown by the fact that only a very slight erosion of that formation took place. Neither did the erosion of the St. Clair limestone enrich the deposits, as is shown by the fact that the richest deposits are found where the St. Clair never was present.

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[a] Purdue, A. H., op. cit., p. 471.

[b] Ulrich, E. O., personal communication.

[c] Purdue, A. H., op. cit., p. 466.

WEST-CENTRAL ARKANSAS.[a]

GEOGRAPHY AND TOPOGRAPHY.

The west-central Arkansas manganese-bearing region consists of a belt extending from Pulaski County on the east, west-southwestward through Saline, Garland, Hot Spring, Pike, and Montgomery counties to Polk County on the west. It varies in width from 4 to 12 miles.

The region consists of a series of nearly parallel mountain ridges grouped together under the name of Ouachita Mountains. The ridges have a general east and west trend, but vary in direction on either side. South of the Ouachita Mountains is the low pine-clad region of southern Arkansas, and north of them are other mountain ranges.

GEOLOGY.

The Ouachita Mountains are formed chiefly of rocks of Ordovician, Silurian, and Devonian age, consisting of novaculite, chert, shale, sandstone, and quartzite. To the north and south are rocks of Carboniferous age, representing the flanks of the anticlinorium of which the Ouachita Mountains form the center. Horizontal beds of Cretaceous, Tertiary, and Quaternary rocks border the disturbed region on the south and east.

Manganese and iron ore deposits are associated with a hard gray novaculite of late Silurian and Devonian age. They occur in veins or in a layer at the top of this bed, in various forms, from mere stains to a network of thin pockets and seams. The ore-bearing layer varies from 4 or 5 to 50 feet in thickness. The novaculite bed has a thickness varying between 300 and 500 feet, is composed of almost pure silica, and varies from a hard translucent white, gray, or buff rock with conchoidal fracture to a soft porous or granular rock with irregular fracture.

The novaculite bed and the ore-bearing layer constitute the Silurian and Devonian formations of this region.[b] They are overlain by a thick series of Pennsylvanian shales and sandstones and underlain by various Ordovician formations consisting of sandstones, shales, and chert.

The rocks of the Ouachita area are very much disturbed, being thrown into a series of close, parallel, approximately east and west folds. The valleys are occupied by the shale formations, and the more resistant sandstone, chert, and novaculite formations form the ridges and mountains. All the rocks are tilted at steep angles. (See fig. 22.)

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[a] Penrose, R. A. F., jr., op. cit., pp. 301 et seq.

[b] Ulrich, E. O., unpublished notes.

CHARACTER AND OCCURRENCE OF ORES.

The ores are oxides of manganese, largely black or steel-blue psilomelane in botryoidal masses, and fibrous or granular black pyrolusite. They frequently occur in intimate association, the pyrolusite incrusting masses of psilomelane and lining cavities in them. Other oxides may be present, but have not been identified.

Iron ores of various types occur in the novaculite ore-bearing layer in pockets with or without manganese ores, and also in lenticular layers in the lower part of the overlying Pennsylvanian shales.

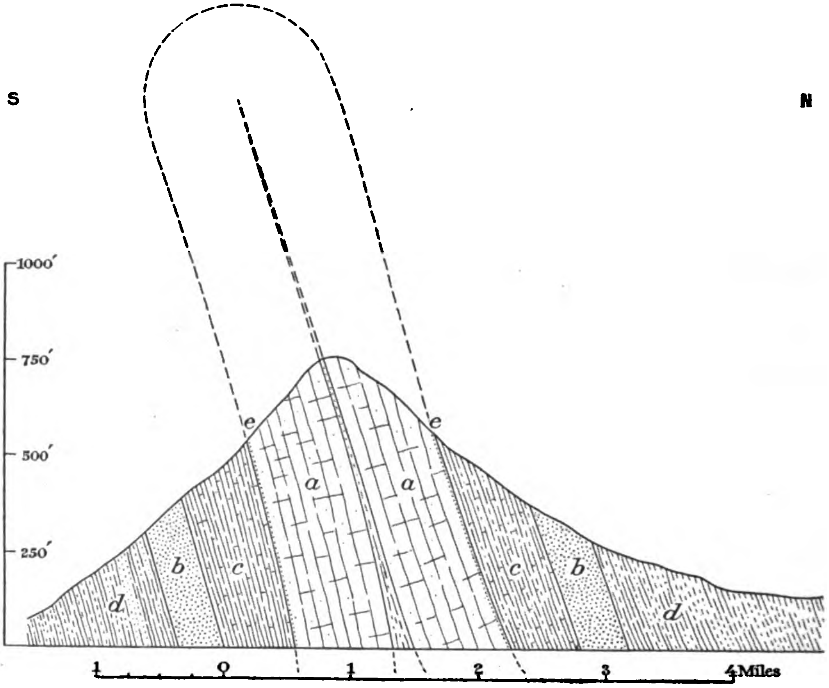

FIGURE 22.—Section showing the occurrence of manganese ores in west-central Arkansas. (After Penrose.) *a*, gray novaculite; *b*, sandstone; *c*, siliceous shale; *d*, shale and sandstone; *e*, manganese-bearing layer.

The types found in the ore-bearing layer are generally glossy dark-brown or black ores in botryoidal masses, while those in the shale are ordinary siliceous brown ores. All the iron ores are hydrated sesquioxides.

The manganese ores occur in nests, pockets, and short discontinuous seams from a fraction of an inch to a foot thick. Thicknesses of a foot, however, are rare; few single masses are more than 3 or 4 inches in greatest thickness. Such bodies are scattered in varying quantities through the ore-bearing layer. They occupy bedding planes or joint cracks, occur as local segregations in the rock, or form a cement in a novaculite breccia. The iron and manganese ores may occur intimately mixed or in separate masses in the same pocket, and thus form manganiferous iron ores, or they may occur in separate pockets.

Manganese and iron stains and small ore pockets extend over the same area as the upper portion of the novaculite bed, though they are only locally concentrated to any degree. They generally occur on both sides of the anticlinal ridges, of which the novaculite bed forms the summit. (See fig. 22.) The principal deposits occur in Pulaski, Montgomery, and Polk counties, and even these are of little or no commercial importance.

A deposit of bog manganese, with clay and rock fragments, is found on the banks of McHenry Creek, Pulaski County. It varies in thickness from a few inches to 10 feet and is mixed with considerable bog-iron ore. The ore is black, massive, and earthy, and in some places composes most of the bed, while elsewhere the rock fragments and clay form the larger portion. The deposit is underlain by gray clay.

ANALYSES.

The following are analyses of psilomelane and pyrolusite from west-central Arkansas:

Analyses of psilomelane and pyrolusite from west-central Arkansas.[a]

	Psilomelane.[b]	Pyrolusite.[c]
MnO	73.17	76.90
O	15.11	16.66
Fe_2O_3	.26	1.06
Al_2O_3	6.52	.79
CoO	Trace.	Strong trace.
CaO	1.58	.52
BaO	.05	2.83
MgO		.14
K_2O	2.12	.26
Na_2O	2.35	.20
P_2O_5	Trace.	
SiO_2	.15	[d]1.52
	101.31	99.88

[a] Penrose, R. A. F., jr., op. cit., pp. 314-315.
[b] Southwestern Montgomery County.
[c] Southeastern Polk County.
[d] And insoluble matter.

The following are analyses of manganese ores and manganiferous iron ores from west-central Arkansas:

Analyses of manganese and manganiferous iron ores from west-central Arkansas.[a]

Locality.	Mn.	Fe.	SiO_2.	P.	Moisture.	MnO_2.
Polk County	60.28			0.413		
Do	58.36		9.02			
Do	55.80	0.60	3.72	.038		
Do	51.54			.167		
Do	48.65	2.03	11.86	.308		
Do	48.34			.449		
Do	40.51	25.53	.80	.767		

[a] Penrose, R. A. F., jr., op. cit., pp. 318-319.

Analyses of manganese and manganiferous iron ores from west-central Arkansas—Cont'd.

Locality.	Mn.	Fe.	SiO_2.	P.	Moisture.	MnO_2.
Polk County	27.68	35.39	1.88	0.230		
Do	26.20	16.83	29.00	.343		
Do	22.84		.42	.047		
Do	11.93	22.26	44.40	.576		
Do	2.06	50.38		1.450		
Pulaski County	40.39	2.17	29.30	.003		
Do	13.31	.87	74.79	.015		
Hot Spring County	41.54	14.15	1.29	.560		60.58
Pike County, Line Mountain	30.93	9.21	5.86	.320		42.09
Montgomery County, Fancy Hill Mountain	48.02	5.55	.52	.310		71.73
Montgomery County, North Mountain	56.66	.18	.15	Trace.		82.10
Polk County, McKinley Mountain	49.24	2.04	2.98	.380		71.41
Polk County, Tall Peak Mountain	52.16	4.00	.24	.390		77.60
Polk County, Manganese Mountain	42.75	2.72	10.46	.450		62.75
Polk County, Cossatot Mountain	59.55	.74	.52	None.		90.52

The following are analyses of bog manganese and iron ores from McHenry Creek, Pulaski County:

Analyses of bog manganese and iron ores from McHenry Creek, Pulaski County, Ark.[a]

	1.	2.	3.	4.	5.
Mn	59.68	27.34	8.08	1.62	0.39
Fe	3.09	2.88	11.82	27.07	33.80
SiO_2	4.83	42.83	63.19	46.37	44.91
P	.001	.116	.270	.470	.160
Moisture		1.42	3.67	3.26	3.02

[a] Penrose, R. A. F. jr., op. cit., p. 330.

CENTRAL TEXAS.[a]

The manganese deposits of central Texas occur in the area of crystalline and metamorphic rocks of probable pre-Cambrian age, in Mason, Llano, and San Saba counties. The ores are directly associated with quartzites and gneisses, though micaceous and garnetiferous schists are frequently found in their neighborhood. Paleozoic and Cretaceous rocks border the crystalline area on all sides and form the capping of many hills within the area.

CHARACTER AND OCCURRENCE OF ORES.

The ores consist of a mixture of oxides and silicates. The former are largely psilomelane and pyrolusite; the latter consist of the manganese garnets spessartite and andradite, the manganese epidote piedmontite, and the manganese olivine tephroite. The oxides have been derived from the oxidation of the silicates.

The ores occur in lenticular layers in both quartzites and gneisses. The layers follow the strike of the inclosing rocks, varying in thickness from a few inches to several feet, and contain many lenses of the inclosing rock. Deposits have been traced for half a mile or more, but within this distance they probably thin out and reappear again several times.

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[a] Penrose, R. A. F., jr., op. cit., p. 432.

The oxide ores are composed of a mixture of hard, massive black psilomelane with conchoidal fracture and soft granular pyrolusite. Considerable silica is associated with them, sometimes in amounts of 15 to 25 per cent.

The silicates are mostly manganese garnets and piedmontite, tephroite occurring but rarely. Spessartite is the manganese-alumina garnet, and andradite a calcium-iron garnet, which here contains a considerable admixture of manganese. The andradite is of two varieties, one chocolate-brown, the other deep yellow. The spessartite is lemon-yellow and the tephroite varies from gray to greenish gray. The piedmontite has a bright-red color. The silicates occur both in crystalline and in massive form.

The following are analyses of the different silicates:

Analyses of manganese silicates from central Texas.

	1.	2.	3.	4.
SiO_2	35.93	37.24	36.24	28.57
Fe_2O_3	4.60	31.17	15.91	5.52
Al_2O_3	18.08	Trace.	11.23	2.46
MnO	31.77	20.11	30.72	58.86
CaO	8.48	10.16	2.04	.30
MgO	.69	[a]1.32	2.22	.80
BaO	Trace.			
K_2O	.17		[a]1.64	.27
Na_2O				
CO_2				2.92
TiO_2	Trace.			
Loss at 105°	.03			
Loss on ignition	.36			
	100.11	100.00	100.00	99.70

[a] Difference.

1. Spessartite from Horse Mountain.
2. Brown andradite from Kothmann tract.
3. Yellow andradite from Kothmann tract.
4. Tephroite from Kothmann tract.

The oxide ores have been derived from the silicates by oxidation, and are intimately mixed with them, but are more abundant near the surface. The alteration varies in different parts of the deposit, being far advanced where the deposit is considerably fractured and slight in places where it is solid. At many points silicates may be found outcropping at the surface. The oxidation follows joints and cracks and proceeds from these inward.

DESCRIPTIONS OF MINES AND DEPOSITS.

The best known of the manganese deposits of central Texas are those of the Spiller mine, of the Kothmann tract, and of Horse Mountain.

Spiller mine.—The Spiller mine is in Mason County, 15 miles northeast of Mason. The deposits are found in lenticular layers interbedded with quartzite, with which are associated beds of mica schist and feldspathic rocks. The rocks dip west or southwest at angles varying up to 45°. They form a north and south hill with a gentle western dip slope, and a steep rugged eastern slope where many layers form almost vertical ledges.

The ores are on the west slope, the lenses running parallel to the direction of the hill. They consist largely of hard steel-gray oxide blending into softer finely crystalline pyrolusite. The oxides are associated with yellow manganese silicates, in great part much decomposed and oxidized. The greatest thickness of solid ore reported is 3 feet on the outcrop, and beneath this is a mixture of lenses of yellow silicates interlayered with quartzite. Scattered deposits are found at intervals along the slope of the hill.

Kothmann tract.—The Kothmann tract is 3 miles southeast of the Spiller mine. Manganese deposits occur here as lenticular beds interbanded with gneiss on the west slope of a north and south ridge. The hill consists largely of gneiss, but garnetiferous and micaceous schist are associated with it. The rocks strike north and south and have a nearly vertical dip. The lenses, three of which are known, consist of manganese silicates stained black at the surface. They have the same strike and dip as the inclosing gneiss, and occur at different levels on the slope. The lowest of them has been followed for one-half mile along the hillside; it consists of chocolate-brown andradite and quartz, the former decomposed to black oxide near the surface and along cracks. It is 2 to 10 feet thick and contains many subordinate lenses of schist or gneiss. The second bed consists largely of impure yellow andradite with associated biotite, hornblende, and feldspar, but at its southern end it contains considerable tephroite. This deposit is discontinuous, varying, where present, up to 3 feet in thickness. Like the lower layer, it is somewhat oxidized at the surface, the tephroite more so than the andradite. The third lens, which is on the summit, has a composition similar to the lowest.

Horse Mountain.—Horse Mountain is in Llano County, 5 miles north of Llano. It consists of fine-grained gneisses cut by quartz veins. The rocks have a north and south strike and dip westward at angles varying from 20° to 40°. The principal manganese deposit occurs on the eastern slope, interbedded with the gneiss; its greatest thickness is 2 feet. It consists of yellow spessartite and red piedmontite,[a] with veins of quartz, lenses of gneiss, and disseminated particles of magnetite. On the surface the deposit is considerably altered to black oxide. It is traceable for 400 yards along the slope, but is very irregular, at many places thinning out or becoming disseminated in the country rock. Several other occurrences of manganese silicates are known on Horse Mountain in association with iron ores.

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[a] Paige, Sidney, Economic resources of the central Texas mineral region, with a report on the pre-Cambrian geology and iron ores: Bull. U. S. Geol. Survey (in preparation).

ANALYSES.

The following are analyses of central Texas manganese ores:

Analyses of manganese ores from central Texas.[a]

Locality.	Mn.	Fe.	SiO_2.	P.	CaO.
Spiller mine	57.87	1.28	5.28	0.012	....
Do	64.60	2.22	10.22	.012	....
Do	48.54	3.30	21.12	.024	....
Do	56.57	1.10	5.85	.042	....
Do	61.59	....	....	.025	....
Do	42.75	....	9.70	....	....
Kothmann tract	15.57	21.82	37.24	....	10.16
Do	23.79	11.14	36.24	....	2.04
Do	45.58	3.86	28.57	....	.30
Horse Mountain	24.60	3.22	35.93	None.	8.48

[a] Penrose, R. A. F., jr., op. cit., p. 440.

Analyses of manganese ores from the Spiller mine, Texas.[a]

	1.	2.	3.	4.
MnO_2	....	1.48	Trace.	3.06
Mn_2O_3	56.63	36.12	....	66.64
MnO	....	....	29.04	....
Fe_2O_3	9.00	7.50	18.35	7.63
Al_2O_3				
CaO	3.05	8.90	9.74	.73
MgO	1.31	Trace.	Trace.	Trace.
H_2O	....	....	....	3.00
P_2O_5	Trace.	Trace.	Trace.	....
SO_3	Trace.	....	....	....
SiO_2	11.47	46.15	43.10	19.13
	81.46	100.15	100.23	100.19
Mn	51.33	26.07	22.48	48.32
P	Trace.	Trace.	Trace.	....

[a] Penrose, R. A. F., jr., op. cit., p. 441.

MINOR DEPOSITS.

TENNESSEE.

A small deposit of manganese ore outcrops on the banks of a small stream near Whitfield, Hickman County, Tenn. This was mined as early as 1837, being the first manganese deposit worked in the United States. The ore was used in coloring pottery, a small quantity, measurable in pounds, being mined yearly.

MISSOURI.

Manganese and manganiferous iron ores are reported by Pumpelly to occur in the porphyritic region around Pilot Knob in Iron, Reynolds, and Madison counties in association with the iron-ore deposits.

On the Cuthbertson-Buford Hill[a] in this region several deposits occur. The deposit on the Cuthbertson tract consists of manganese ore in irregular tabular masses as float or imbedded in red ocherous clay. The ore is red sesquioxide with a probable admixture of peroxide. The deposit at the Buford bank on the same hill consists of manganiferous iron ore, which occurs imbedded in clay, similarly to the Cuthbertson ore. In Reynolds County[a] a black oxide of manganese is reported as occurring in stringers in one of the members of a series of bedded porphyry rocks. Considerable manganese ore has been mined at Arcadia, Iron County.[a]

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[a] Weeks, J. D., Mineral Resources U. S. for 1885, p. 347.

In the porphyry of Shannon and Carter counties,[b] southwest of the Pilot Knob area, manganese of remarkable purity is said to occur locally in veins varying from mere seams to 3 inches in thickness.

The following analyses show the composition of the Pilot Knob ore:[a]

Analyses of manganese ore from the Pilot Knob region.

	Cuthbertson tract.	Buford bank.	Reynolds County.	Arcadia, Iron County.	Arcadia, Iron County.
MnO	68.20	15.84	37.04		
MnO_2			5.48		
Fe_2O_3	3.30	68.30			
Insoluble siliceous material	.44	8.54	45.55		
S		.017			
P_2O_5		.102			
Mn	52.47	12.32		64.98	58.02
Fe		47.81		2.82	3.35
P		.044		.04	.03

Manganese also occurs in the Ozark region[c] in association with Paleozoic sediments. In Howell County it forms a cement in sandstone at a number of localities. In Carter County it occurs as cement in chert breccia, and locally also as kidneys in associated clay. Masses of chert breccia are sometimes 10 feet thick.

OKLAHOMA.

Deposits of manganese ore are reported from a locality 15 miles west of Lehigh,[d] Okla., and small quantities have been mined.

The ores consist of black oxide and red, gray, or brown carbonates occurring together in beds or pockets in Ordovician and Silurian limestones, the carbonates being the most abundant. The beds are said to lie on limestone of Ordovician age and to be overlain by other limestones. Many pockets occur along faults, and surface bowlders are found in many places over Ordovician and Silurian rocks.[e]

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[a] Weeks, J. D., Mineral Resources U. S. for 1885, pp. 347, 348.

[b] Nason, Frank, Iron ores of Missouri: Missouri Geol. Survey, vol. 2, pp. 20, 95.

[c] Nason, Frank, op. cit., pp. 94, 95.

[d] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 413.

[e] Taff, J. A., personal communication.

The following analyses show the nature of the ores:

Analyses of manganese ores from Lehigh, Okla.

Mn.	Fe.	Si.	P.	Moisture.
39.66	6	1.40	0.055	4.05
39.67	6.15	1.45	.066	4.57
43.18	5.72	1.70	.060	3.25
38.54	6.76	1.20	.053	4.05
40.50	8	1.50	.050	3.70
35.78	8.09	....	....	....
51.78	2.46	.30	.053	....
59.55	3.07	.75	.026	....
40.28	4.92	.85	.046	....
43.18	1.23	1.30	.036	....
49.34	1.84	2.00	.053	....
53.35	5.53	.60	.056	....
42.71	....	....	.050	....

COMMERCIAL IMPORTANCE OF THE ORES.

The only ores of commercial value in the Mississippi Valley and Gulf region are those of the Batesville district, which has been one of the most important producers. Though the other deposits are of much interest geologically, their small size and the character of their ore make it unlikely that they will ever be mined to a great extent.

No ore is being mined at present in the Batesville district, but a large amount has been produced during the last twenty-five years, more than 10 per cent of all the manganese ore mined in the United States having come from this district. There is still considerable ore in sight, and it is probable that a much larger quantity remains to be discovered, though it would be unwise to make any estimate of the amount available.

The principal reason for the cessation of operations is the fact that the ores require too much treatment to prepare them for the market, and that even when prepared they are of low grade. They are generally high in phosphorus and therefore not as desirable in the steel industry as the eastern or the foreign ores. The presence of a large amount of hard braunite and psilomelane, and the absence of high-grade pyrolusite, also make them less desirable for oxidizing and other chemical purposes than the pyrolusite and psilomelane of the Appalachian and Piedmont regions. Nevertheless it is beyond doubt that when foreign ores, which are now playing so important a part in our steel industry, become scarce, the Batesville district will again join the ranks of important producers.

LAKE SUPERIOR REGION.

CHARACTER AND OCCURRENCE OF ORES.

In the Lake Superior region manganese is found in two forms, (1) as oxide in many of the iron-ore deposits, forming a manganiferous iron ore, and (2) as bog manganese.

The iron ores of many of the deposits of the Lake Superior district contain a percentage of manganese ranging up to 6 and even 10 per cent. This ore, while not directly utilized in the manufacture of ferromanganese and spiegeleisen, yet furnishes a manganiferous pig iron which is distinguishable from ordinary pig iron and is used for special purposes.

Manganese or manganiferous iron ores occur in the Huronian rocks as pockets in the hematite deposits. Occasionally streaks of high-grade manganese ore, mainly pyrolusite, are found, but they are too small and too much scattered to be separated from the ordinary iron ores. Such ores have been mined and are being mined on the Mesabi, Gogebic, Marquette, and Menominee iron ranges, and are being exploited on the Cuyuna and Baraboo ranges.

Deposits of bog manganese occur near Wilson, St. Croix County, and in other localities in northern Wisconsin.

The following are analyses of Lake Superior manganiferous iron ores:

Analyses of Lake Superior manganiferous iron ores.[a]

	1.	2.	3.
Fe	58.21	55.70	56.80
Mn	4.50	7.40	5.75
SiO_2	3.22	3.30	3.20
Al_2O_3	.80	.98	.98
CaO	.27	.30	.24
MgO	.14	.07	.18
P_2O_5	.059	.040	.071
S	None.	.016	.10

[a] Birkinbine, John, Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, 1899, p. 133.

Analysis of manganiferous iron ore from the McComber mine, Negaunee, Mich.[a]

Fe_2O_3	71.43
Mn oxide	17.25
Al_2O_3	2.20
P_2O_5	.073
SO_3	.073
SiO_2	2.05
H_2O+	5.32
Undetermined	1.604
	100.000
Fe	59.80
Mn	10.90
P	.034
S	.021

[a] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 415.

Average analyses of manganiferous iron ores shipped from the Lake Superior region in 1892.[a]

	1.	2.	3.	4.	5.	6.
Fe	44.47	50.00	47.94	52.62	57.00	56.36
Mn	8.00	5.00	12.03	9.99	5.00	4.89
SiO_2	9.42	7.50	....	....	....	....
P	.100	.115	.046	.058	.063	.055
Moisture	5.60	7.00	....	9.96	....	....

[a] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 414.

Average cargo analyses of Lake Superior manganiferous iron ores of the seasons 1906 and 1907.[a]

Mine and season.	Fe.	Mn.	P.	SiO_2.	Al_2O_3.	CaO.	MgO.	S.	Moisture.
Gogebic range.									
Bonnie:									
1906	45.30	5.01	0.029	10.46	1.04	0.27	0.08	0.012	11.09
1907	45.56	5.41	.048	11.79	1.29	.27	.42	.010	9.34
Castile: 1907	50.86	1.40	.221	7.329	.28	.80	.24	.014	14.97
Cary Bessemer:									
1906	50.87	2.02	.051	9.41	.90	.20	.29	.006	9.00
1907	49.11	2.19	.048	10.30	1.06	.24	.32	.009	10.00
Cary Empire:									
1906	50.97	2.28	.055	8.88	.91	9.19	.17	.011	9.00
1907	49.00	3.21	.052	10.49	1.04	.19	.20	.013	9.00
Cary Manganese:									
1906	50.35	3.26	.055	8.05	.90	.20	.29	.006	9.00
1907	47.98	3.76	.048	10.16	.98	.19	.22	.010	10.00
Newport:									
1906	47.63	6.56	.037	6.00	.52	.28	.12	.012	10.97
1907	47.35	7.83	.046	6.52	1.09	.027	.15	.017	9.95
Ottawa:									
1906	51.16	3.13	.049	6.867	.90	.135	.43	.005	9.64
1907	50.00	2.88	.046	8.084	.997	.22	.41	.0126	10.18
Ottawa Manganese:									
1906	48.097	5.625	.057	6.039	1.34	.135	.18	.005	10.00
1907	48.499	5.937	.045	6.02	1.37	.18	.31	.009	9.50
Rand:									
1906	53.36	2.81	.036	2.94	....	....	....	....	11.79
1907	54.17	2.39	.037	3.22	....	....	....	....	11.64
Marquette range.									
South Jackson:									
1906	40.21	2.49	.073	25.10	1.42	.27	.10	.016	8.40
1907	40.21	2.49	.073	25.10	1.42	.27	.10	.016	8.40
Menominee range.									
Groveland: 1907	50.37	1.05	.038	10.76	2.39	3.37	4.43	.007	4.05
Manganate:									
1906	47.20	2.64	.559	5.02	2.31	1.89	2.23	.035	2.66
1907	47.10	2.22	.562	5.23	3.42	2.05	2.18	.033	9.07
Manganate No. 2:									
1906	45.66	5.56	.565	4.33	2.22	2.01	2.22	.038	6.46
1907	45.00	4.64	.560	5.92	2.44	1.95	2.20	.038	7.22
Mesabi range.									
Alberta[b]	52.90	1.08	.040	8.42	1.22	.09	.14	.025	10.00
Elba:									
1906	55.46	1.05	.035	4.23	.88	.18	.29	.007	9.00
1907	54.74	.75	.036	6.90	.79	.25	.21	.009	8.00
Hobart[b]	53.10	.95	.074	7.29	1.35	.20	.13	.009	10.00
Kinney: 1907	50.30	1.08	.068	4.93	2.17	.26	.28	.042	13.27
Larkin: 1906	49.42	1.43	.023	13.41	1.16	.19	.25	.022	10.00
Larkin Manganiferous: 1907	43.21	2.26	.024	20.77	1.68	.24	.28	.057	9.61
Mayas Manganese:									
1906	49.72	4.50	.036	7.20	1.50	.207	.207	.009	10.00
1907	46.12	4.37	.042	....	....	....	....	....	11.62
Midway[b]	52.66	2.17	.059	9.38	.77	.09	.12	.010	7.00
Smith: 1906	53.89	1.44	.030	10.27	.61	....	....	....	7.77
Wacotah: 1907	48.89	.91	.056	5.43	....	....	....	....	13.50
Wilpen: 1906	47.83	1.58	.063	5.41	2.94	.21	.11	.013	14.77
Wilpen[b]	52.80	1.20	.062	5.59	2.99	.20	.12	.013	12.00

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[a] Complete average cargo analyses of Lake Superior iron ores, 1906 and 1907, Lake Superior Iron Ore Association.

[b] Expected analysis for the season 1908.

CUYUNA IRON RANGE, MINNESOTA.

Recently considerable manganiferous iron ore has been found during exploration work on the Cuyuna iron range of central Minnesota.[a] The iron ores proper of this district rarely contain more than 0.1 to 0.3 per cent metallic manganese. However, many layers and pockets of manganiferous iron ore are found in them, which may contain as much as 28 per cent metallic manganese.

In general the iron ores of the Cuyuna range occur in steeply dipping beds between a hanging wall of green slate and a foot wall of amphibole-magnetite rock. (See fig. 23.) The ore-bearing bed varies in composition from rich iron ore to lean ore. The rocks are of Huronian age and have been folded into a series of close anticlines and synclines. At many places where erosion has cut away the upper portion of the anticlines several parallel bands of iron formation are found.

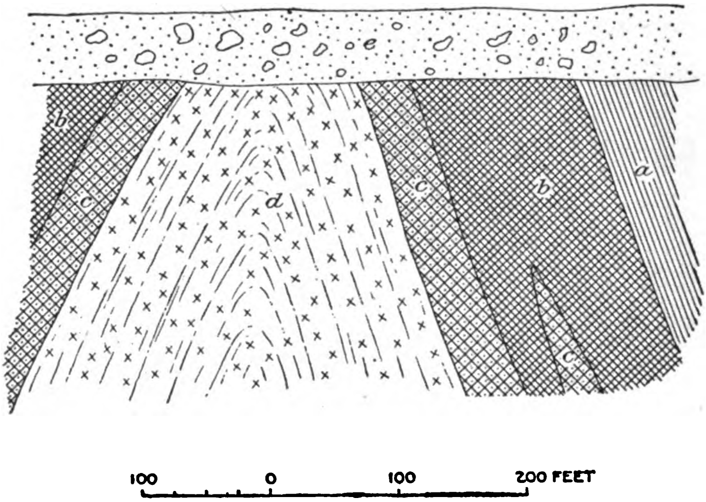

FIGURE 23.—Sketch showing the occurrence of manganiferous iron ores in iron-ore deposits of the Cuyuna range, Minnesota. *a*, Green slate; *b*, iron ore; *c*, manganiferous iron ore; *d*, amphibole-magnetite rock; *e*, glacial drift.

The iron-ore beds locally contain lenses and layers of manganiferous iron ore of various sizes. Different layers of this material, as well as different parts of the same layer, differ greatly in composition; some contain from 1 to 10 per cent manganese; others contain up to 25 or 30 per cent.

Below are given the analyses[a] from two drill holes in characteristic manganiferous iron ore. The first shows the high-grade and the second the ordinary type of this ore.

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[a] Zapffe, Carl, Brainerd, Minn., personal communication.

Analyses of high-grade Cuyuna manganiferous iron ore from specified depths in drill hole.

Depth in feet.[a]	Mn.	Fe.	SiO_2.
47-50	27.88	23.20	16.22
50-55	13.52	29.57	....
55-60	13.51	37.84	....
60-64	14.87	32.18	....
64-65	13.65	34.16	17.57
65-70	15.37	29.89	....
70-75	4.46	49.49	....
75-80	4.86	49.19	....
80-85	6.76	47.58	11.65
85-90	7.32	46.25	....
90-97	6.79	47.24	....
97-100	11.25	39.70	....
100-105	7.98	47.36	13.97
105-110	7.21	38.82	....
110-115	9.61	33.90	....
115-120	12.40	34.12	....
120-125	10.72	44.07	12.39
125-130	10.96	45.48	....
130-131	15.77	40.16	....
131-135	19.84	33.96	....
135-140	15.02	28.03	26.29
140-145	19.00	18.69	....
145-150	24.33	27.91	....
150-155	23.06	28.56	....
160-165	6.96	25.66	46.33
165-168	5.44	28.92	....
168-170	10.28	28.54	....
170-175	7.77	28.33	....

[a] Surface drift occupied the top 45 feet. To a depth of 260 feet the hole was in ore and ore-bearing rock, and from 260 to 275 feet in chloritic schist, or amphibole-magnetite rock.

Analyses of Cuyuna manganiferous iron ore of the ordinary grade from specified depths in drill hole.

Depth in feet.[a]	Mn.	Fe.	SiO_2.
53-60	3.01	31.15	....
60-65	2.75	24.95	....
65-70	3.90	29.63	....
70-75	3.02	27.69	47.32
75-80	1.28	30.64	....
80-85	2.79	29.00	....
85-90	2.34	35.06	....
90-95	3.41	29.69	43.12
95-100	4.58	27.75	....
100-105	4.27	23.35	....
105-110	5.28	22.04	....
110-115	5.67	19.28	52.31
120-125	1.42	34.35	....
135-140	2.34	31.60	....
145-150	2.61	29.77	....
175-185	1.42	36.18	42.53
185-190	1.70	36.73	....
190-195	1.18	37.26	....
195-200	1.17	31.43	....
205-210	.96	37.85	39.70
235-240	4.79	40.46	....
360-365	6.36	41.98	....
365-370	12.24	38.47	....
370-375	9.91	34.79	22.17
375-377	10.63	40.76	....

[a] Surface drift occupied the top 53 feet.

ROCKY MOUNTAIN REGION.

GENERAL STATEMENT.

The manganese ores of the Rocky Mountain region, with a few exceptions, belong to the class of manganiferous silver ores. Most of them contain a considerable percentage of iron. Such deposits occur at Leadville and a few smaller localities in Colorado, at Silver City, Kingston, and Lake Valley, N. Mex., at Tombstone, Ariz., and at Neihart and Castle, Mont. Manganiferous silver ores with little or no iron occur at Butte, Mont. Manganiferous iron ores are found on Taylor Peak and in the Cebolla Valley, Colorado, and near Wickes, Mont.; and manganese ores proper are found in Custer County, S. Dak., in the Little Grande district, Utah, and in negligible quantities in Steuben Valley and Sapinero, Colo. So far only the manganiferous silver ores have been utilized.

BUTTE DISTRICT.

GEOGRAPHY AND TOPOGRAPHY.

The Butte district is situated around the city of Butte, Silver Bow County, southwestern Montana, a short distance west and north of the Continental Divide. It is roughly 10 miles square, but the principal mines are confined to a much narrower limit. The city of Butte is on the north slope of a broad valley, in which is the head of Silver Bow Creek, and on the opposite side of which is the Continental Divide. The mines are located on the slopes within and around Butte, on the ridge to the north, and in the valley to the southeast. The elevation of the district ranges from 5,400 feet above sea level in the valley to 6,500 feet on the ridge north of Butte.

GEOLOGY.

The rocks of the Butte district are all of igneous origin, being Cretaceous and Tertiary intrusives and eruptives. The following list gives the rocks arranged according to their age:[a]

- Pleistocene:
  - Alluvium.
- Tertiary:
  - Lake beds.
  - Rhyolite.
- Post-Carboniferous:
  - Quartz porphyry.
  - Bluebird aplite.
  - Butte granite.

The Butte granite is the characteristic rock of the district. It covers by far the larger part of the ore-bearing area and contains most of the mineral veins. It is a coarse, dark-colored rock containing, as principal constituents, orthoclase, plagioclase, quartz, hornblende, and biotite.

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[a] Emmons, S. F., Weed, W. H., and Tower, G. W., jr., Butte special folio (No. 38), Geol. Atlas U. S., 1897; also Weed, W. H., Ore deposits of Butte, Mont.: Bull. U. S. Geol. Survey No. 213, 1903, p. 170; and Jour. Geology, vol. 7, 1899, pp. 744-747.

The granite around Butte is part of a large granite batholith extending from the Highland Mountains, 20 miles southwest of Butte, to Helena. This mass is surrounded by altered limestones and other sediments and partly covered by dark-colored andesite, both of which are older than the granite. Neither sediments nor andesite, however, are found in the vicinity of Butte. The other rocks of the Butte district are of later age and occur as intrusives in the granite or as flows over it.

The Bluebird aplite is found most abundantly in the western part of the district. It consists of phenocrysts of alkali feldspar, quartz, and small quantities of biotite and plagioclase in a white or brownish sugary matrix. It is intrusive into the Butte granite in dikes or irregular sheets and masses of varying size, but is supposed to have originated from the same magma as the granite, and at but a slightly later period, as the dikes show no chilling effects along the contact.

The quartz porphyry consists of phenocrysts of white feldspar, mainly orthoclase, altered to sericite, and glassy quartz in a fine-grained dense groundmass. It is intruded into both granite and aplite in lenticular dikes. After its intrusion there was considerable fracturing and formation of veins, which traverse granite, aplite, and porphyry. The formation of veins was followed by renewed volcanic activity, resulting in the intrusion and eruption of rhyolite.

The intruded rhyolite is massive and forms dikes and masses in the older formations, many of the dikes cutting veins of ore. The eruptive rhyolite is fragmental and forms large sheets, consisting of tuffs and breccias. Locally there are areas of rhyolite which consist of a mixture of both phases. The mineral composition of the rhyolite differs in different localities. The principal constituents, however, are sanidine, plagioclase, quartz, and biotite, occurring as phenocrysts in a glassy to fine-grained groundmass. The rock is light in color, varying from gray to reddish. After its eruption there was more fracturing and vein formation.

West of the district there are Miocene lake beds, consisting of sands, gravels, and tuffs, the last being of the same age as the rhyolitic tuffs mentioned above. Alluvium conceals the underlying formations in the valley of Silver Bow Creek.

OCCURRENCE OF THE ORES.

The ores of the district are found in veins traversing both the granite and the aplite, and in some parts the porphyry. The ores are of two kinds, copper and silver. The former occur in an east and west oblong area, the western part of which is in the city of Butte.

The silver-bearing veins occur in a much-larger area surrounding the copper area on the north, west, and southwest sides. At their boundary there are veins of mixed copper and silver ores.

The veins, both copper and silver, occur in three distinct systems. The oldest veins have an east and west trend, those of the second set are northwest-southeast in direction and displace the east and west veins, while those of the third set, northeast-southwest in direction, displace the veins of both of the earlier sets. The veins of the first two systems are heavily mineralized, while those of the last consist mainly of fault débris with ore fragments from the earlier veins.

The copper veins contain chalcocite, enargite, bornite, and cupriferous pyrite in a gangue of quartz and included granite. Covellite occurs in a few mines, while tetrahedrite and chalcopyrite are very rare. Chalcocite, enargite, and cupriferous pyrite are abundant throughout the area. Bornite is practically restricted to the western portion; there, however, it is abundant. Manganese minerals are notably absent from the copper area, except where it borders the silver-bearing area. The tungstate of manganese, hübnerite, however, has been found at the Gagnon mine.

The upper portions of the copper veins consist of quartz stained by iron. This passes at a depth of several hundred feet into copper ore bodies, which consist mainly of sulphides, but which are somewhat oxidized and decomposed in their upper portions. Carbonates and oxides are rare. Several copper veins were worked for silver in the upper oxidized part, and it is believed by many mining men that silver veins in the surrounding district pass downward into copper.

The silver veins in the lower unoxidized portion consist of silver sulphide, zinc blende, galena, and pyrite. Chalcopyrite and tetrahedrite occur rarely, adjacent to the copper-bearing area. These minerals are found in a gangue of quartz, rhodonite, and rhodochrosite, quartz being the most abundant. Rhodonite and rhodochrosite occur in streaks and masses scattered irregularly through the quartz. They are intimately mixed, but rhodonite is said to be more abundant near the center, and rhodochrosite on the outskirts of the veins. The silver veins show marked banding and crustification and generally include numerous large and small lenses of granite.

Near the surface the veins are oxidized and consist mainly of quartz and manganese oxide, probably wad, carrying silver. The quartz occurs in small veins or lenses varying in thickness from one-eighth inch up, which run either with or across the direction of the main lode. The spaces between the ramifying quartz veins are filled with manganese oxide, which as a rule predominates over the quartz. Included lenses of granite are abundant.

The veins vary from a few feet to 100 feet in thickness. Their contact with the granite is not very sharply defined, owing to numerous small anastomosing veins in the granite adjacent to the lodes. Commonly a vein divides into two, which may run along parallel for some distance and then join again, or may branch off from each other at considerable angles.

The unoxidized portions of the veins are light-colored, varying from white where quartz predominates to pink where rhodonite and rhodochrosite are most abundant. Here and there the metallic minerals form darker areas. The included masses of granite in the veins are yellow and are generally more decomposed than the main body of granite. They form a large portion of the lode.

The oxidized portions have a black appearance, due to the presence of manganese oxide, which results from the oxidation of the rhodonite and rhodochrosite. The change from oxidized to unoxidized ores takes place at depths between 150 and 300 feet in the Black Rock mine, where both phases are typically developed.

The Butte manganiferous silver veins are at present being worked only on a small scale by lessees of the old properties. The ores are used for their precious-metal content only, the manganese minerals in them being valuable, however, for fluxing purposes. Ores with a considerable percentage of these frequently draw a higher price than the same grade of ore with little or no manganese.

In the early days of the district, when silver was the main output, small quantities of oxidized manganiferous ore were mined in the aplite area west of Butte and sold simply for flux. At present, however, the manganese is only indirectly utilized.

The following are analyses of oxidized ores from Butte:

Analyses of Butte oxidized manganiferous silver ores.[a]

	1.	2.	3.
Mn oxides	88.40	47.60	21.00
Fe oxides	3.20	12.40	7.70
SiO_2	6.60	34.20	66.40
Al_2O_3	....	3.70	2.40
Ag	[b].03	[c].11	[d].275
S	....	Trace.	....
Moisture and loss	1.77	1.99	2.22
	100.00	100.00	99.995

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[a] Penrose, R. A. F., jr., Manganese: Its uses, ores, and deposits: Ann. Rept. Arkansas Geol. Survey for 1890, vol. 1, 1893, p. 454.

[b] 9 ounces.

[c] 32 ounces.

[d] 80 ounces.

WICKES AREA.

GEOGRAPHY AND GEOLOGY.

The Wickes manganese deposit is in Jefferson County, Mont., about 6 miles north of Wickes station. It is near the head of a small gulch in a low range of mountains a short distance east of the Continental

Divide, at an elevation of about 6,000 feet above sea level. The deposit lies in a little flat area several hundred yards long in the bottom of the gulch, which is perhaps a few hundred feet wide at this point. Above and below the level area the bottom of the gulch has a steep grade. The slopes are wooded with pine and fir.

The slopes of the gulch on either side of the manganese deposit consist of granite, which is part of the granite batholith extending northeastward from Butte.[a] Immediately south of the deposit and extending beyond Wickes is an area of late igneous rocks consisting of light-reddish dacitic rhyolite and andesite porphyry.

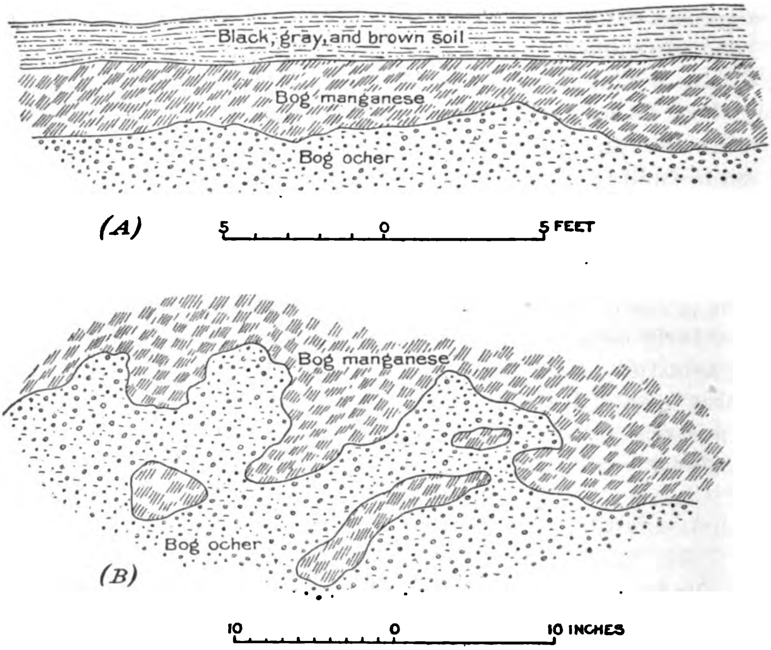

FIGURE 24.—Sections through the bog manganese deposit near Wickes, Mont. *A*, General section through the ore bed; *B*, detailed sketch of the bog manganese and ocher contact.

OCCURRENCE OF THE ORES.

The deposit is in a horizontal bed and consists of a mixture of bog manganese and bog limonite, the latter being largely ocher. It occupies part of the level area at the bottom of the gulch. Trenches have been made testing the deposit to a depth of about 5 feet and a horizontal extent of about 50 feet. How far it extends beyond these limits is not known.

Above the deposit there are 1½ feet of brown and black earth, with an admixture of decayed leaves and wood. The upper part of the deposit itself consists of bog manganese; the lower part is largely brown and yellow ocher. The bog manganese ore is porous and consists of a skeleton or network of glossy black hard ore with intervening cavities filled with black powder. The bog-iron ore has a globular texture, the globules being about half as large as peas and consisting of yellow ocher, and the intervening spaces are filled with hard glossy brownish-black limonite. In some places the limonite takes the place of considerable masses of ocher, forming a hard, solid ore.

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[a] Weed, W. H., unpublished map of the region between Butte and Helena, Mont.

The contact of the two types of ore is very irregular (see fig. 24), small irregular and rounded masses of manganese ore being included in the ocher and small masses of ocher in the bog manganese.

The ore is in all probability derived from the leaching of manganese minerals, such as rhodonite and rhodochrosite, in the granite. These minerals may be disseminated through the rock, or they may be in veins, as at Butte. They were dissolved by meteoric waters, and the manganese and iron were carried down the slopes, partly on the surface, but probably largely below the surface. At or near the bottom of the gulch the waters issued as springs, and were allowed to settle in the little level area and deposit their load in the form of surface bog ore.

LEADVILLE DISTRICT.

GEOGRAPHY AND TOPOGRAPHY.

The Leadville district is situated around the city of Leadville, in Lake County, Colo. Leadville is on a bench or terrace 10,000 to 10,400 feet above sea level on the west slope of the Mosquito Range, the higher summits of which rise above it to an elevation of 13,000 and 14,000 feet above sea level. West of Leadville is the Arkansas Valley, about 700 feet lower. The Mosquito Range forms the eastern slope and the Sawatch Range the western slope of the upper Arkansas Valley. The deposits from which most of the ore of the district has been taken are within 2 and 3 miles east of Leadville, but more recently considerable mining has also been done west of the city.

GEOLOGY.

The rocks of the Leadville district are of both igneous and sedimentary origin, ranging in age from Archean to Quaternary. The following table gives the general succession for the region:[a]

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[a] Emmons, S. F., The geology and mining industry of Leadville, Colo.: Mon. U. S. Geol. Survey, vol. 12, 1886, pp. 45 et seq.; Emmons, S. F., and Irving, J. D., The Downtown district of Leadville, Colo.: Bull. U. S. Geol. Survey No. 320, 1907, p. 21.

Succession of rocks in Leadville district, Colorado.

SEDIMENTARY ROCKS.

	Feet.
Quaternary:	
Wash.	
Lake beds.	
Carboniferous:	
Upper Coal Measures	1,500
Weber grits Weber shales	2,500
Leadville blue limestone	200
Devonian: Parting quartzite	30
Silurian: White limestone	160
Cambrian: Lower quartzite	160

IGNEOUS ROCKS.

Eruptive (Tertiary):	
Rhyolite and andesite.	
Intrusive (Mesozoic):	
Diorite, porphyrite, and porphyries.	
Gray porphyry	50
White porphyry	800
Archean: Granite.	

The surface distribution of these formations is very complicated on account of an abundance of faulting and folding. In general there are two lines of displacement along the Mosquito Range, one on the west side of the crest and the other on the east side. They join northeast of Leadville and only one fault continues northward. The eastern fault has a northwest-southeast direction throughout its extent; the western fault has the same direction in the southern part of the district, but in the northern part its course is a little east of north, and the single fault north of the junction continues in that direction. Both faults have the downthrow side to the west. In the ore-bearing district proper, immediately around Leadville, there is considerable minor faulting.

Northeast of Leadville the granite forms the summit and the upper slopes, both east and west, of the Mosquito Range. The Weber formation, with areas of porphyry and rhyolite, forms the lower western slope, being separated from the granite by the fault, and older Paleozoic rocks form the lower eastern slope. South of the junction of the two faults, Paleozoic sediments, ranging from Cambrian to Carboniferous, with large areas of gray and white porphyry, occupy the crest and east slope of the range as far down as the east fault. The Weber formation forms the lower and larger portion of this area. The granite occupies the upper part of the west slope as far down as the west fault, beyond which the Weber again appears, giving place westward to successively lower Paleozoic rocks, down to the granite that occupies the lower slopes. The area east of the eastern fault is formed by Paleozoic rocks, the oldest being on the west. The Arkansas Valley and the lower slopes on either side are occupied by Quaternary material. Across the Arkansas Valley is the Sawatch Range, composed largely of granite. Immediately east of Leadville the rocks consist of granite, porphyry, and Paleozoic sediments, with complicated areal distribution due to faulting.

The Archean rocks are of three types,[a] granite, gneiss, and amphibolite. The granite is the most abundant of these. In places it is coarse grained and porphyritic, elsewhere fine grained, and varies in color from red to gray. Its essential minerals are quartz, orthoclase, microcline, plagioclase, muscovite, and biotite. It contains veins of pegmatite consisting of quartz, feldspar, and muscovite.

The gneiss contains quartz, orthoclase, plagioclase, hornblende, and mica. The mica is largely biotite, but muscovite is present locally in small quantities. It has a typical gneissoid structure, in many places consisting of alternating bands of light and dark material due to variation in amount of mica and hornblende. In some places it is porphyritic, and in others it has a tendency to granitic texture.

Amphibolites are interstratified with the gneisses in beds or lenses. They consist mainly of quartz, orthoclase, plagioclase, and hornblende, and in many places biotite is prominent. The gneiss and amphibolite form the main mass of a series which contains, besides, mica schist, phyllite, and other schistose rocks.

The Cambrian lower quartzite consists mainly of white saccharoidal quartzite with an upper shaly portion which grades into the overlying siliceous Silurian limestone. At the base there is a thin persistent bed of fine-grained conglomerate, composed of pebbles of blue quartz about the size of peas. Above this is the white quartzite, and above that calcareous quartzites and shales of various nature.

The Silurian white limestone is a drab-colored compact dolomite containing considerable silica. It is thinly bedded, commonly has a conchoidal fracture, and at certain horizons contains concretions of white chert.

The "Parting" quartzite is a thin but persistent white quartzite between the Silurian white limestone and the Carboniferous formations.

The Leadville limestone is heavy bedded and generally dark grayish blue, but ranges from drab to almost black. It is granular in texture, the upper part being in many places coarsely crystalline. Black chert concretions of irregular shape, many of them hollow in the center, are very characteristic of this upper portion. The Leadville limestone is a normal dolomite containing about 20 per cent magnesia and 30 per cent lime.

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[a] Emmons, S. F., loc. cit.

The Weber formation consists of alternating calcareous and carbonaceous shales and quartzitic sandstones below, passing into coarse sandstones above. The shales form a transition zone several hundred feet thick between the massive Leadville limestone and the coarse sandstones of the Weber. These consist typically of coarse white sandstones passing into layers of conglomerate with quartz pebbles. Both contain fragments of feldspar, and in many places the sandstones contain considerable white mica, and also carbonaceous material. Next in importance to the sandstones and conglomerates are quartzose shales and mica schist, composed of quartz, feldspar, and muscovite. Thin layers of black carbonaceous shales occur at irregular intervals. Several beds of the gray dolomitic limestone are found near the middle of the series.

The "Upper Coal Measures" have at the base a nondolomitic compact limestone. Above this are calcareous and siliceous beds passing upward into red shales and sandstones.

The lake beds consist of fine-grained to coarse-grained stratified beds of slightly consolidated clay, sand, and rock fragments, with an abundance of marl, especially in the lower portion. They are of glacial origin and are supposed to have been deposited as broad deltas in a lake in the upper Arkansas Valley, formed by a glacial dam, the materials of which issued from Lake Creek valley in the Sawatch Range.

The wash is an unsorted glacial deposit of rock fragments and sand, of somewhat later origin. Both lake beds and wash in most places conceal the underlying rocks in the district around Leadville.

The white porphyry is a white compact rock composed of quartz, feldspar (mainly orthoclase), and muscovite. It is in the form of an intrusive sheet lying directly above the Leadville limestone.

The gray porphyry is a decomposed greenish-gray rock, in many places in the mines bleached and reduced to a pasty white mass. It occurs characteristically as a thin intrusive sheet near the middle of the Leadville limestone bed.

The other intrusives and Tertiary eruptives occur in several parts of the district, but they are not closely associated with the ore-bearing district proper.

OCCURRENCE OF THE ORES.

With regard to occurrence, the Leadville ores have been divided into three classes[a]—upper-contact ores, second-contact ores, and third-contact ores. (See fig. 25.) The upper-contact ores occur in the Leadville limestone between the white and gray porphyries, generally directly underneath the white porphyry. The second-contact ores occur in the Leadville limestone beneath the gray porphyry.

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[a] Emmons, S. F., and Irving, J. D., op. cit., p. 36.

The third-contact ores are in the Silurian white limestone underneath the "Parting" quartzite. Ores of the first class are by far the most abundant and are richest in silver. Ores of the second type contain a fair amount of silver, while those of the third type are low grade.

The ore bodies are irregular in shape and in many places pay ores grade imperceptibly into low-grade ores and finally into the inclosing country rock. This is especially true where the country rock is limestone, the contact with the porphyry being more regular.

NATURE OF THE ORES.

The ores of the Leadville district are of two classes—unoxidized and oxidized.[a] The former consist of pyrite, galena, zinc blende, and a small quantity of silver sulphide. Silver sulphide is contained mechanically or in actual combination in all the other minerals, though principally in galena and zinc blende.

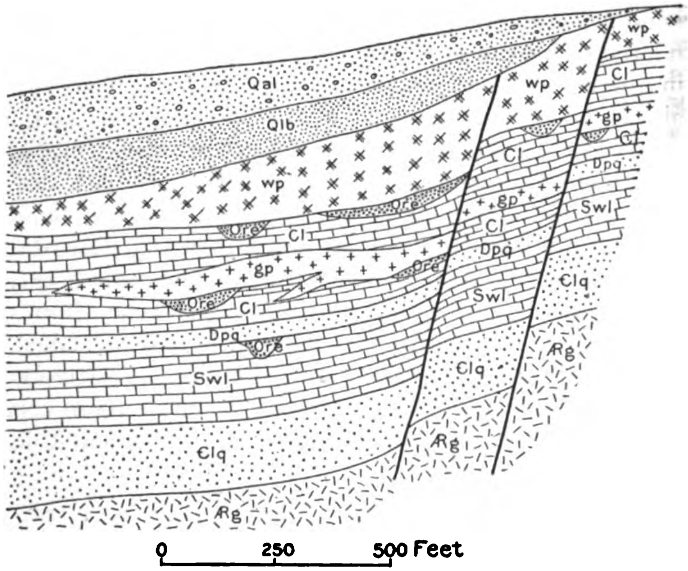

Figure 25.—Typical section showing the occurrence of the ore deposits at Leadville, Colo. (Modified from Emmons and Irving.) Qal, Wash; Qlb, lake beds; wp, white porphyry; Cl, Leadville limestone; gp, gray porphyry; Dpq, "Parting" quartzite; Swl, white limestone; Ɛlq, lower quartzite; Ʀg, granite.

The oxidized ores consist of lead carbonate and silver chloride in a gangue of iron and manganese oxides. The galena changes first to lead sulphate (anglesite) and finally to cerussite. In some of the richer deposits pyromorphite, the chlorophosphate of lead, is occasionally found. Sphalerite changes to hydrous zinc sulphate, which, being very soluble, is carried downward and probably deposited in the upper part of the unoxidized portion of the deposit. There is, therefore, practically no zinc in the oxidized ores. Silver sulphide alters to the sulphate, which is readily soluble and becomes widely distributed through the ore bodies. Its stable form is the chloride, which is greenish and contains small amounts of the bromide and iodide. It generally occurs along cracks in the other minerals, though in some of the richer deposits it is found in small bodies. Native silver occurs rarely. The iron sulphides alter to the hydrous sulphate, melanterite, which changes partly to the basic ferric sulphate, but mainly to limonite, the hydrous sesquioxide, and which, together with manganese oxides and silica, forms the gangue of the other ores. Silica is the principal nonmetallic mineral found as gangue in the Leadville deposits, though calcite and barite are present.

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[a] Emmons, S. F., and Irving, J. D., op. cit., pp. 32 et seq.

The unoxidized ores contain an average of not over 1 per cent manganese, the mineral form of which is not known, for both rhodonite and rhodochrosite are conspicuously absent. The oxidized ores contain amounts of manganese varying in general from 15 to 25 per cent, although they may be as little as 10 per cent and as much as 40 per cent. The manganese is in the form of oxide, probably wad, and is intimately mixed with the limonite, giving it a brown-black color. It is most abundant in the upper parts of the deposits near the overlying porphyry and diminishes in quantity downward.

As a reason for this abnormal increase of manganese in the oxidized ores, it has been suggested that part of it was leached from the overlying porphyry.[a] As a further suggestion it may be asked whether the other constituents may not have diminished relatively to manganese and silver by leaching, inasmuch as both these constituents are more abundant in the oxidized ores than in the sulphide ores.

USES OF THE ORES.

The Leadville ores are used for three purposes, according to their grade: (1) For their lead and silver content; (2) for their iron and manganese content in the manufacture of spiegeleisen and ferromanganese; and (3) for their iron and manganese oxides as flux in smelters.

(1) The high-grade ores are used for their lead and silver content. Those having a considerable quantity of iron and manganese oxides often draw a higher price because of the fluxing value of these constituents.

(2) Those ores which are too low in lead and silver to be utilized for these metals, but are high in manganese and iron, are commonly used in the manufacture of spiegeleisen and ferromanganese.

(3) A considerable portion of the ores are of too low grade for either of these purposes, but still contain considerable iron and

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[a] Emmons, S. F., and Irving, J. D., op. cit., pp. 34-35.

manganese oxides and some lead and silver. Such ore is used for fluxing purposes in the smelters. The oxides of iron and manganese assist in smelting the higher-grade lead-silver ores, but finally become waste in the form of slag. The lead and silver content is recovered, as it mixes with the lead and silver obtained from the higher-grade ores.

Most of the Leadville ore used in the manufacture of iron alloys is sent to the Pueblo furnaces, but some of it has gone as far east as Joliet, Ill.

PRODUCING MINES.

The principal mines in the Leadville district which have produced manganiferous silver ore recently are the Evening Star, Morning Star, Grey Eagle, Little Chief, A. V. shaft, and Seneca. Those of minor importance are the Big Chief, Catalpa, Excelsior, Robert Emmet, Crescent, Hibschle, All Right, and Penrose.

ANALYSES.

The following tables show the composition of the Leadville manganiferous silver ores:

Analyses of Leadville oxidized ores.[a]

	Siliceous hematite from Chrysolite mine.	Iron ore from Kenosha mine.
Insoluble	8.20	21.10
Fe_2O_3	54.14	7.70
MnO_2	22.36	65.98
ZnO	2.56	1.00
H_2O and ignition	12.709	4.22
Ag	.031	.012
	100.00	100.00

[a] Emmons, S. F., Mon. U. S. Geol. Survey, vol. 12, 1886, Appendix B, Chemistry, by W. F. Hillebrand, p. 602, analysis 495.

Analyses of manganiferous iron ores from Leadville district.[a]

	Catalpa mine.	Crescent mine.	Crescent mine.	George A. Hull.	Emmett mines.	Emmett mines.	([b])
Mn	21.30	34.00	31.00	19.30	35.36	38.22	30.98
Fe	34.90	17.80	21.15	35.00	11.00	11.45	23.30
SiO_2	6.90	6.30	7.00	3.83	8.06	5.02	5.71
Al_2O_3	4.15			2.00	2.37		1.26
CaO	.34			.46	1.23		1.56
MgO	.07			.45	1.36		.57
S	.06	.027			.33		.068
P	.04	.056			.111		.038
Cu	Trace.			.03			
Pb oxide				1.85			
H_2O				2.96	18.06		
Volatile				9.36			

[a] Weeks, J. D., Sixteenth Annual Rept. U. S. Geol. Survey, pt. 3, 1895, p. 409.

[b] Stated to be a fair average of the better grade of manganiferous iron ore as shipped in 1894.

Analyses of manganese ores and manganiferous iron ores from Leadville and vicinity, Colorado.[a]

Name of mine or owner.	Manganese.	Iron.	Silica.	Phosphorus.	Sulphur.
Fannie Barrett	51.20	6.20	2.90	0.007	....
Fuller	49.20	6.00	15.00	.129	0.041
....	40.56	1.33	4.70	Trace.	.137
Pennsylvania mine	38.60	2.05	4.00	....	....
Evening Star mine	37.14	12.20	7.60	.022	.075
J. B. Henslee	36.40	19.50	7.00	.025	.027
John Harvey	34.64	18.20	8.00	.033	....
Crescent-Catalpa mines	34.00	17.80	6.30	.045	....
Fannie Barrett	33.00	6.20	6.10	.008	....
George W. Hull	29.12	25.10	3.80	.084	....
Ballou	24.69	32.14	4.40	.022	.178
Catalpa mine	20.20	34.12	6.50	.008	.082
Do	20.14	36.82	6.83	.007	.021
Parks & Hull	19.30	35.00	3.83	.045	....
Henslee	18.66	28.42	8.49	.040	....
George W. Hull	18.11	30.86	4.04	.039	....
Do	16.20	43.30	3.10	.012	....
Maid and Henrietta mines	14.71	41.48	5.00	.039	.055
Ballou	9.30	48.51	4.20	.017	.055

[a] Penrose, R. A. F., jr., op. cit., p. 464.

Analyses of manganiferous ores, with amount of silver per ton, from Leadville and vicinity, Colorado.[a]

Name of mine or owner.	Manganese.	Iron.	Silica.	Silver per ton.
				Ounces.
Gray Eagle mine	29.65	18.10	11.40	7.50
Do	27.30	17.00	13.30	6.00
Do	23.25	25.10	7.42	11.55
Do	27.50	20.60	8.60	....
Dunkin mine	7.40	45.50	8.40	7.70
Do	8.90	43.10	12.50	....
Maid of Erin mine	11.20	39.40	6.20	4.50
Do	16.80	33.20	9.80	4.60
Do	22.50	28.60	9.40	5.70
Do	14.60	38.20	7.60	3.20
Do	19.50	36.60	5.20	2.70
Little Chief mine	17.80	32.15	8.30	8.90
Do	15.30	39.90	6.30	....
Castle View mine	20.00	27.50	7.42	6.10
Do	24.90	26.50	4.00	1.55
Do	25.40	26.10	4.70	1.20
Do	21.60	27.40	7.90	....
Yankee Doodle mine	13.10	28.50	14.30	6.70
Coronado mine	25.20	28.30	7.20	11.60
Do	26.60	25.10	7.00	....
Morning Star mine	17.40	31.20	14.00	10.30
Morning and Evening Star mines	17.60	31.50	8.30	....
Do	20.10	32.30	6.70	....
Iron Silver Mining Co	28.80	17.45	10.80	12.70
Do	24.15	21.80	9.80	4.60
Do	24.70	25.65	8.45	6.55
O. K. mine	10.80	38.00	15.20	5.40
Tobin	9.00	41.30	11.10	4.60
Horner	20.30	26.80	11.60	2.65
Sulphide Mining Co	9.55	43.40	9.00	2.90
Do	9.30	41.20	11.80	2.80
Bison mine	24.70	31.50	8.30	....
Do	25.80	22.20	10.30	....
Matchless mine	6.20	44.70	13.80	....
Do	6.80	44.40	13.60	....
Starr Lease	26.20	22.50	6.50	....
Great Hopes Mining Co	9.40	45.40	10.20	....
Leadville Consolidated Mining Co	33.70	15.20	9.00	....
Seneca Mining Co	16.60	35.00	9.20	....

[a] Weeks, J. D., Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 302.

Average analyses of Colorado manganiferous silver ores used for the manufacture of spiegeleisen.[a]

	1.	2.	3.	4.	5.	6.	7.
Mn:							
Minimum	31.15	22.25	31.30	18.15	26.35	26.40	14.15
Maximum	35.05	25.75	37.90	23.15	33.20	28.30	21.85
Average	33.14	23.52	36.70	19.96	29.96	27.30	19.60
Fe	17.05	26.99	8.30	23.70	23.80	22.75	29.70
SiO_2	7.97	4.31	11.70	10.55	6.75	6.50	10.60
P	.061	.060	.053	.047	.033	.115	.052
CaO	1.18	1.55	3.25	1.14	.68	1.84	1.84
Al_2O_3	1.32	1.21	3.50	3.25	1.49	1.53	2.25
MgO	.79	.97	1.15	1.06	.45	.85	1.15
S	....	....	.12	.13	.096	.090	.15
Zn	.180	....	2.10	....	....	2.00	.90
Pb	....	....	.30	....	....	.15	....
Moisture	14.80	14.96	16.100	12.00	12.60	14.100	14.28

[a] Weeks, J. D., Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 301.

Average analyses of Colorado manganiferous silver ores used for fluxing.[a]

	1.	2.	3.	4.
Mn:				
Minimum	8.50	9.00	19.33	15.10
Maximum	19.70	25.25	34.80	35.00
Average	10.00	17.00	28.30	24.15
Fe	40.00	38.00	23.00	26.45
SiO_2	10.00	12.00	7.60	7.04

[a] Weeks, J. D., Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, pp. 303–304.

LITTLE GRANDE DISTRICT.

GEOGRAPHY AND TOPOGRAPHY.

The Little Grande district is about 10 miles southwest of Little Grande, a station on the Rio Grande Western Railway in east-central Utah. It is a short distance east of Green River in a rough, barren region. The nearest town is Green River, 25 miles northwest, where the railroad crosses Green River.

The topography is typical of the Colorado Plateau—broad uplands and steep canyons. Everywhere are bare rock exposures and none but desert vegetation exists. Directly south of the principal part of the area there is an immense steep-walled chasm, many hundred feet deep and several miles wide, with sides and bottom of red sandstone carved into fantastic shapes. Here vegetation is almost totally absent.

The manganese ore is on a broad bench above the chasm; beyond to the north are undulating ridges and intervening canyons and valleys formed by alternating hard and soft layers of rock.

GEOLOGY.

The rocks of the manganese area and the adjacent country are sediments of Triassic, Jurassic (?), and Cretaceous age. The line of division between the first two has not been definitely established in this region, however. The manganese district itself is supposed to be in the Jurassic area, while Little Grande station and the town of Green River are in the Cretaceous area.

The following shows roughly the lithologic succession:

Succession of rocks in Little Grande manganese district, Utah.

Upper Cretaceous:[a]
  Gray sandstone (Mesaverde formation). Great thickness. Exposed north of the Rio Grande Western Railway.
  Gray shale (Mancos shale). Great thickness. Exposed south of the Rio Grande Western Railway.
  Buff sandstone, in many places conglomeratic (Dakota sandstone).
Unconformity.
Jurassic (?):
  Light-colored sandstones and variegated shales. Several hundred feet.
  Massive brownish-white sandstone. 100+ feet.
  Light-green and purple shale. 50+ feet.
  Thin layer of manganese oxide. (Unconformity?)
  Thin-bedded, red, calcareous sandstones and limestones. Several hundred feet.
Triassic: Heavy-bedded red sandstone, probably the Vermilion Cliff sandstone. Great thickness.

The beds have a gentle dip to the north, so that the formations are successively older southward. The chasm immediately south of the deposits has its bottom and lower walls formed by massive red sandstone (probably Vermilion Cliff), which is carved by wind erosion into rounded fantastic forms. The upper part of the walls and the bench on which the deposits occur are red calcareous sandstones and siliceous limestones. The ridges to the north are formed by overlying sandstones and shales of questionable age though probably largely Jurassic, and by the Cretaceous gray shale (Mancos shale). The area occupied by the Jurassic (?) beds contains steep-sided canyons; in the Mancos shale area are broad shallow valleys.

OCCURRENCE OF THE ORES.

The manganese ores occur in several adjacent areas, the largest about 5 miles in length. They are in the form of surface blankets, where the rocks have been eroded down to the thin-bedded red sandstone and limestone formation. These blankets consist partly of surface float and partly of replacements in the red limestones near or at the surface. The rocks are at or very near the surface throughout most of the area, disintegration having rarely reached more than a few feet below the surface. Small fragments of ore, generally less than 4 inches in diameter, are abundant in the disintegrated red sand

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[a] Richardson, G. B., Reconnaissance of the Book Cliffs coal field between Grand River, Colorado, and Sunnyside, Utah: Bull. U. S. Geol. Survey No. 371, 1909.

and clay and on the surface. In the solid rock underneath this, and in the rock where it crops out at the surface, there are local irregular replacements, which in few places extend downward more than a foot or two from the surface. Some of these are in small specks or irregular masses; others follow distinct layers and bedding planes, and such replacements cover wider areas and are more thorough. Layers 3 to 4 inches thick are sometimes found entirely replaced by manganese oxide.

Manganese and iron stained chert occur abundantly in the red limestones and as float, but are not directly associated with the ore.

The manganese deposits do not appear to be in a definite bed, but rather in an undulating zone at the top of the thin-bedded red sandstone and limestone formation. This might suggest a possible erosion period after the deposition of that formation, during which small amounts of manganese oxide were deposited over a considerable area. The manganese may have been derived from eroded portions of the red sandstone and limestone formation, in which it may have been present in small quantities as manganese carbonate, or it may have been brought in from the outside. It was probably deposited as oxide. After the deposition of the overlying sediments and the reemergence and consolidation of the entire series, the manganese oxide became solid and crystalline.

The ore is soft and is steel-gray or blue, consisting mainly of crystalline and granular pyrolusite. The crystalline ore is more common where openings have been filled, and with it is calcite in specks and seams. The granular pyrolusite is more abundant in the solid limestone, where there has been direct replacement of calcium carbonate by the manganese oxide.

MINOR DEPOSITS.

SOUTH DAKOTA.

Wad and bog limonite occur associated in fissures and horizontal layers[a] in Carboniferous limestone at Jewel Cave in Hell Gate Canyon 13 miles west-southwest of Custer, Custer County, S. Dak. The principal deposit is on the west slope of the canyon, where there is a vertical fissure 1 to 2 feet wide in the limestone. The fissure strikes northeast-southwest and is connected with a number of thin horizontal layers, which run out from it between the limestone layers. The deposit as exposed extends through a vertical distance of about 40 feet. In some of the layers the ore is associated with calcite cave deposits. The ore for the most part is a mixture of hydrated oxides of iron and manganese, though locally wad occurs alone. It is soft and light and of low grade, a type specimen of the best grade yielding only 27.9 per cent manganese. The following is a section by Schrader[a] showing the succession of the horizontal layers through which the upper portion of this vein passes:

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[a] Schrader, F. C., unpublished notes.

Section of upper portion of manganese deposit at Jewel Cave, S. Dak.

	Ft.	In.
Soil		9
Limestone fragments and soil	2	
Reddish-buff subsoil		9
Wad		6
Hard, finely bedded iron-stained limestone with layers of wad and soft limonite one-half to 3 inches thick	2	
Reddish-brown clay		6
Wad		6
Wad and soft limonite with clay and calcite at the base	1–3	
Coarsely crystalline calcite in pyramidal forms directed downward		9
Yellowish-brown soft limonite	1–2	
Fine-grained semicrystalline limestone	1–2	

From the form of the deposit it appears that the manganese probably came into the fissure from the surface and spread from it along horizontal planes. Numerous fragments of wad occur locally on the floor of Jewel Cave.

Manganese ore of much higher grade than that described above has been reported from Custer County, but the locality is not known. It is said to contain from 30 to 92 per cent peroxide of manganese and from 0.05 to 0.4 per cent phosphorus. The following is an analysis of this ore:

Analysis of manganese ore from Custer County.[b]

Mn	46.05
Fe	3.93
P	.05
SiO_2	8.00
Moisture	4.70

MONTANA.

Manganiferous silver ore similar to the Leadville ore occurs at Neihart, Cascade County, and at Castle, Meagher County, Mont.[c] At Neihart the ore is in the form of brown and black oxides in the upper portions of the veins, and grades below into sulphide ores of silver. They are associated with barite. A small amount of manganiferous silver ore has been mined at a few mines in the vicinity of Neihart, principally the Galt mine, and sent to the Great Falls smelters to be used for flux. As a rule, however, the ore is used for its silver and lead only, though when an appreciable amount of manganese and iron oxides are present the smelting charges are reduced, because of their fluxing value.

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[a] Schrader, F. C., unpublished notes.

[b] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 423.

[c] Idem, p. 417.

The manganiferous silver ores from the Galt mine have the following composition:

Analyses of manganiferous silver ore from the Galt mine, Montana.[a]

	1.	2.	3.	4.	5.
Mn	6.9	9.6	6.7	5.9	7.7
Fe	5.5	6.5	5.8	5.3	6.9
Pb	8.7	5.6	6.0	9.1	4.6
Zn	6.9				
SiO_2	18.8	23.2	21.4	26.7	27.0
Al_2O_3	[b] 6.0	[b] 6.0	[c] 6.0	[c] 6.0	5.9
$BaSO_4$	28.3	23.4	25.2	22.2	20.5
S	5	4.2	5	3.5	4.5
Ag (ounces per ton)	128.7	72.0	77.4	105.6	54.3

[a] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 418.

[b] Approximate.

At Castle there are large veins of black oxide of a purer quality than those at Neihart, which carry small amounts of lead.

Recently manganiferous ores have been reported from Martinsdale, Meagher County.

COLORADO.

Manganiferous silver ores occur in several other metalliferous deposits in Colorado besides Leadville, as in Eagle County and in the San Juan district.

Manganese and manganiferous iron ores occur in small quantities in the iron-ore deposits in several localities. Among these are the deposits of Taylor Peak in the Elk Mountains on the border of Pitkin and Gunnison counties and those of Cebolla Valley, in the southern part of Gunnison County. Small deposits of manganese ore are found in Steuben Valley and near Sapinero, Gunnison County.

The iron-ore deposits of Taylor Peak[a] contain manganiferous iron ore of the following composition:

Analysis of manganiferous iron ore from Taylor Peak, Colorado.

MnO	13.92
Fe_2O_3	39.01
CaO	19.55
MgO	6.03
CO_2	21.05
SiO_2	.82
	100.38
Mn	10.78
Fe	27.31

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[a] Penrose, R. A. F., jr., Manganese: Its uses, ores, and deposits: Ann. Rept. Arkansas Geol. Survey for 1890, vol. 1, 1893, p. 458.

Analyses of manganiferous iron ore from Taylor Peak, Colorado.[a]

	1.	2.
Mn	19.815	10.492
Fe	29.25	24.70
P	.003	.035
CaO	4.46	24.67
MgO	3.145	.81
SiO_2	3.405	.765

[a] Birkinbine, John, Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 304.

In the Cebolla Valley[a], 2 miles above Powderhorn post-office, manganese oxide is associated with limonite and clay, which constitute surface alterations of iron-ore bodies. The rocks of this locality consist of granite, quartzite, and limestone overlain by trachyte flows. The iron-ore deposit is associated with the limestone as a bed apparently conformable with it. It consists of magnetite and hematite intimately interbedded with fine and coarse grained iron carbonate. At the surface the iron carbonate is altered to limonite and clay, with the development and introduction of chlorite, chalcedony, and manganese oxide, the last in some ores running as high as 45.92 per cent in metallic manganese. This surface alteration is principally confined to the area adjacent to the trachyte capping.

The following is an analysis of manganese ore from Cebolla Valley:

Analysis of manganese ore from Cebolla Valley.[b]

Mn	41.43
Fe	3.08
SiO_2	19.68
P	.36
Co	Trace.

In Steuben Valley,[c] 6 miles southwest of Gunnison, black siliceous manganese oxide occurs in a series of lava flows and breccias. The breccia consists of fragments ranging up to several feet in diameter in a sandy matrix of the same material. The ore occurs in cavities in it and forms the matrix in which many of the lava fragments are embedded. In this manner it impregnates considerable masses of breccia. Seams and stains of ore are sometimes found in the massive lavas overlying the breccia.

Manganese also occurs in a certain bed in the massive lavas as a hard glossy black oxide in pockets and veins from one-half inch to 6 inches thick. The rock in which it occurs is a yellow brittle translucent rock with conchoidal fracture embedded as an oblong pocket 4 feet thick in a layer of black obsidian-like rock.

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[a] Leith, C. K., Iron ores of the West: Bull. U. S. Geol. Survey No. 285, p. 197; also Penrose, R. A. F. jr., op. cit., p. 456.

[b] Penrose, R. A. F., jr., op. cit., p. 458.

[c] Idem, p. 459.

The following analysis shows the composition of the Steuben Valley ore:

Analysis of Steuben Valley manganese ore.

Mn	36.60
Fe	5.64
SiO_2	35.32
P	.116

The Sapinero[a] deposit consists of black siliceous manganese oxide occurring in a lava breccia similar to that at Steuben Valley. The ore is found in botryoidal forms in cavities ranging up to 4 feet in diameter, or in a network of thin veins from one-eighth inch to 1 inch thick. The breccia bed is overlain by a massive lava bed slightly stained by manganese, and is underlain by a white to brown sandstone of supposed Cretaceous age, which rests directly upon crystalline rocks.

The following is an analysis of Sapinero ore:

Analysis of Sapinero manganese ore.

Mn	27.94
Fe	2.65
SiO_2	31.19
P	.49
Co	Trace.

The Iron Mask group of mines at Gilman, Eagle County, has in recent years produced considerable manganiferous silver ore, which was used in the manufacture of iron-manganese alloys.

Ores of the same nature are said to occur at Telluride and Lake City in the region of the San Juan Mountains.

Psilomelane is reported from the vicinity of Canon City, Fremont County.

NEW MEXICO.

Manganiferous and ferruginous silver ores occur in southwestern New Mexico[b] at Silver City, Grant County, and at Kingston and Lake Valley, Sierra County. The Silver City ores were mined on Legal Tender Hill and are said to have been used as a flux in smelters. They contained an average of 13 per cent metallic manganese. At Kingston the manganese occurs as black oxide and as manganocalcite in veins in blue limestone and black dolomite; at Lake Valley it is in the form of fibrous pyrolusite.

ARIZONA.

Manganese oxide is abundantly developed in the oxidized portions of the metalliferous deposits at Tombstone, Ariz.[b] The ores are used for their silver content only, but the manganese is of assistance as a flux in smelting.

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[a] Penrose, R. A. F., jr., op. cit., p. 461.

[b] Idem, p. 465.

The rocks of the district consist of a series of limestones, quartzites, and shales of probable lower Carboniferous age, associated with porphyritic and feldspathic dikes and granite. The ore occurs mainly in the limestones at the contact with porphyry dikes. The deposits are in the form of veins or chimneys. The ore is principally pyrolusite and earthy black wad, with some psilomelane, and occurs in a calcareous or siliceous gangue.

The following analyses show the composition of the Tombstone ore:

Analyses of manganiferous silver ore from the Big Comet mine, Tombstone, Ariz.

	1.	2.
Mn	15.0	14.8
Fe	1.8	2.0
Pb	1.0	.4
CaO	32.4	34.8
SiO_2	5.2	3.2
Ag	(a)	(a)

[a] $13.45 to $15.75 per ton.

COMMERCIAL IMPORTANCE OF THE ORES.

The manganese deposits of the Rocky Mountain region are small, widely scattered, and few in number, but the manganiferous silver ores are of considerable importance. Besides a few tons shipped from Montana the only manganese ore produced has come from the Little Grande district in Utah. The latter has recently been abandoned, so that at present no manganese ore is being produced in the Rocky Mountain region.

Manganiferous silver ores, however, have been produced in large quantities in many of the precious-metal districts. By far the larger part of this ore has been and is now being used for flux, but a small portion goes annually into the manufacture of spiegeleisen. So far the ore used for this purpose has come altogether from Leadville and vicinity. Of course, only those ores which are low in their percentage of precious metals can be considered as available for their iron and manganese content, and only a small proportion of these is used in steel manufacture, because the price of flux material is such that it does not pay producers to ship their ore to blast furnaces when it can be used in local smelters.

Manganiferous silver ores contain too much iron to be used for chemical purposes.

GREAT BASIN REGION.

GENERAL STATEMENT.

The Great Basin region includes the territory between the Wasatch Mountains on the east and the Sierra Nevada on the west. It is a dry desert region with numerous isolated mountain ranges. The desert areas are underlain by Pleistocene or Recent lake and stream deposits, while the mountain ranges consist of rocks ranging in age from pre-Cambrian to Tertiary.

The manganese ores of the Great Basin have been of no great importance. They consist largely of manganiferous silver ores associated with many of the metalliferous deposits and forming a considerable part of a number of them. Such deposits occur at Pioche and Eureka, Nev., and at Modena and in the Tintic district, Utah. There is a small bedded deposit of manganese ore near Golconda, Humboldt County, Nev., on Humboldt River, and a contact deposit is found near Joy, Juab County, Utah.

GOLCONDA AREA.

GEOGRAPHY AND TOPOGRAPHY.

The Golconda manganese area is in north-central Nevada about 3 miles east of the village of Golconda on the Southern Pacific Railroad. The deposits are in a small area one-fourth mile square, about one-half mile south of where Humboldt River issues from its canyon through the Edna Mountains, which rise about 1,000 to 1,200 feet above the deposits to the east. To the west is the undulating desert valley in which Golconda is situated. The entire region, the mountains as well as the valleys, except a narrow strip along Humboldt River, is destitute of trees, only sagebrush and other desert shrubs being found. Along the banks of the Humboldt grasses, green shrubs, and small trees grow.

GEOLOGY.

The rocks of the region are both igneous and sedimentary, but only the latter are associated with the ore deposits. The igneous rocks in the immediate vicinity are designated in the Fortieth Parallel Survey [a] as granite, propylite, rhyolite, and basalt; the sedimentary rocks are given the following succession:

Succession of sedimentary rocks in Golconda district, Nevada.

Upper Quaternary: Tufa, etc.
Pliocene: Humboldt.
Triassic:
    Star Peak.
    Koipato.

The Edna Mountains are composed largely of Star Peak formation (shales, limestones, and quartzites). The summit is formed by a heavy bed of quartzite, and the west slope is composed of slaty shale with some interbedded layers of limestone and quartzite. The beds dip at angles of 70° to 80° NE., that is, toward the mountains. (See fig. 26.) The shales are hard and slaty and vary in color from greenish or yellowish-gray to brown. The interbedded quartzites are hard and vitreous and contain numerous quartz veins; the limestone beds consist of blue crystalline limestone with abundant thin quartz seams.

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[a] King, Clarence, U. S. Geol. Expl. 40th Par., vol. 2, p. 680 (Arnold Hague), and Atlas.

Near the foot of the mountains there are two small knolls consisting of horizontally bedded tufa, which rests unconformably upon nearly vertical shales. The tufa is of Quaternary age, having been deposited near the shore line at the extreme eastern end of old Lake Lahontan.[a] It is of two varieties, soft calcareous tufa and hard flintlike siliceous tufa, the latter occurring in large masses, many of them several feet thick, through the former. Both contain locally abundant fragments of quartzite and shale identical with the rocks composing the neighboring slopes. The calcareous tufa is brownish white with uneven fracture, and has the general appearance of impure limestone. The siliceous tufa is somewhat lighter in color, is very hard, breaks with conchoidal fracture, and contains small cavities lined with quartz. At the contact these tufas grade into each other. Both rocks are solid and compact.

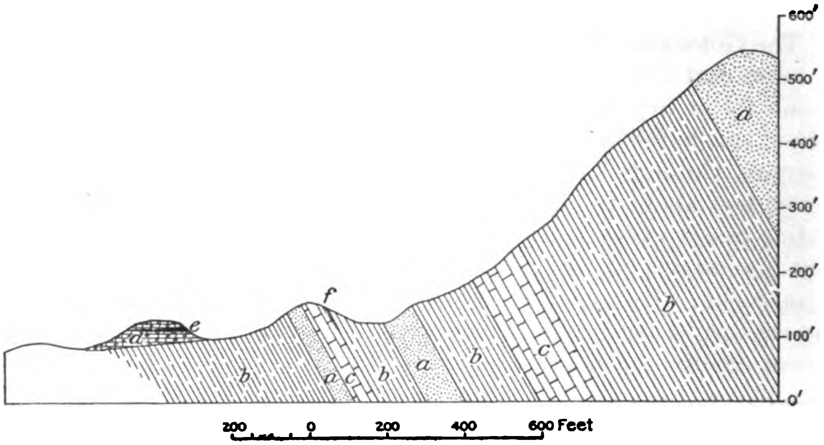

FIGURE 26.—Section showing the relation of the Golconda manganese deposit to the rocks of the Edna Mountains, Nevada. (Modified from Penrose.) *a*, Quartzite; *b*, shale; *c*, limestone; *d*, calcareous tufa; *e*, bedded manganese ore; *f* limonite replacement deposit.

OCCURRENCE AND CHARACTER OF ORES.

The ores of the Golconda area are of two types, (1) a horizontal layer of manganese oxide interbedded with tufa in the little knolls at the foot of the mountains, and (2) replacement deposits of manganiferous limonite along a crystalline limestone layer in the Star Peak formation, a few hundred yards up the slope from the horizontal bed. The first contains limonite locally, while the second is slightly manganiferous in some places. The bedded deposit (see fig. 27) is broadly lens shaped, being several feet thick where thickest and narrowing toward the edges till it consists only of small pockets, stains, and dendritic markings. A large part of the original bed has been removed by erosion, only small portions of it near the top of the two knolls remaining. These have semicircular outcrops on the east sides of the knolls and rapidly die out to the west.

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[a] Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: Mon.; U. S. Geol. Survey, vol. 11, 1885.

The ore is black and friable, and consists of a mixture of hard glossy material and powder, the former composing a skeleton, while the powder fills the intervening spaces. In many parts of the bed there are small rock fragments similar to those in the tufa, some of them largely replaced by manganese oxide. The deposit on the northern knoll is composed of fairly pure manganese ore, while on the knoll to the south the bed is in places made up largely of limonite and ocher.

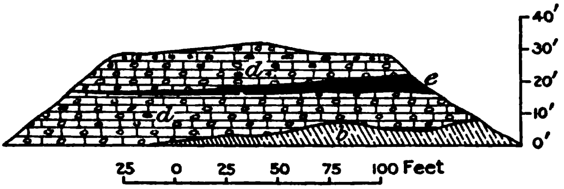

FIGURE 27.—Section through the Golconda manganese deposit, Nevada. (After Penrose.) *b*, Shale; *d*, calcareous tufa; *e*, manganese ore.

The following analysis shows the composition of the Golconda ore. The presence of 2.20 per cent of tungsten is especially noteworthy.

Analysis of manganese ore from Golconda, Nev.[a]

MnO	65.66
O	10.31
Fe_2O_3	3.32
Al_2O_3	0.34
CoO	([b])
CaO	3.44
BaO	5.65
MgO	1.26
K_2O	0.35
Na_2O	None.
H_2O and organic matter	4.16
P_2O_5	None.
WO_3	2.78
SiO_2	1.70
	98.97
Mn	50.85
Fe	2.32
W	2.20
P	None.
Moisture	4.97

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[a] Penrose, R. A. F., jr., op. cit., p. 470.

[b] Appreciable amount.

The replacement deposits in the crystalline limestone bed (fig. 28) consist largely of siliceous materials, limonite, and ocher. They are found along the outcrop for several hundred feet. Their width, as a rule, does not exceed 15 or 20 feet and the depth is not known. The replaced rocks are crystalline limestone with associated thin shale and quartzite layers. The original sedimentary layers may be distinguished in some parts of the deposits.

The crystalline limestone is decomposed, consisting of a network of quartz seams inclosing ocherous powder. With it occur lenses, beds, and irregular masses of brown limonite in various stages of replacement, depending on the rock replaced. Quartzitic layers are stained and only partly replaced; shaly layers are largely replaced, though fragments of the original rock are commonly inclosed. The deposits are mainly limonite, but here and there pockets or seams of manganese oxide occur in them.

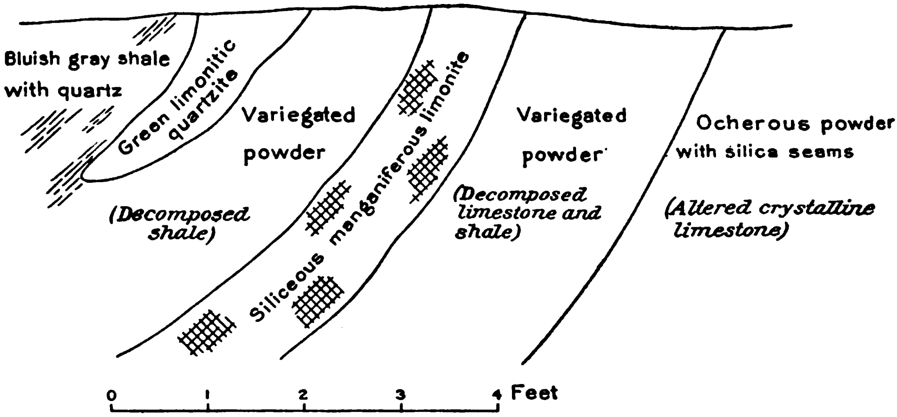

FIGURE 28.—Section through the replacement deposit of manganiferous iron ore near Golconda, Nev.

The bedded deposit of manganese oxide and limonite appears to have been precipitated from solution in an elliptical basin during a lull in the precipitation of calcareous tufa. It is conceivable that while the shore lines of Lake Lahontan were retreating small basins, partly or altogether isolated, should be formed. Waters from hot springs or other sources emptying into these basins would gradually produce in it a concentration of whatever foreign materials they carried, and at length precipitation would occur. It is probable that near the Golconda basin there were hot springs whose waters carried in solution considerable manganese and iron, as the present Golconda hot springs do. If these waters had emptied into Lake Lahontan directly, they would have been widely distributed and there would have been no concentration. In an isolated or partly connected basin, however, precipitation would occur after a considerable period of time. The replacement deposits on the slopes above the bedded deposit may indicate the vents of hot springs. The iron, being more readily precipitated than the manganese, was deposited in greater abundance around these vents, replacing limestones and associated rocks, while the manganese was for the most part carried down into the basin and there precipitated.

After a long period of precipitation there occurred an expansion of the old lake, bringing the shore line back to its original position and resulting later in the continued deposition of calcareous tufa.

MINOR DEPOSITS.

UTAH.

Manganese ores are reported[a] from the vicinity of Joy, Juab County, Utah, 40 miles west of Oasis. The deposit is said to run 4,500 feet along the contact of a limestone and granite, the latter being on the foot wall, and to have been tested to a depth of 110 feet. The ores have the following composition:

Analyses of manganese ores from Joy, Utah.

[Booth, Garrett, and Blair, Philadelphia, analysts.]

	1.	2.
Fe	7.00	5.99
Mn	41.00	42.54
SiO_2	6.25	6.27
P	.143	.159
Al_2O_3	3.68	....

A deposit of manganiferous silver ore is being developed near Modena,[b] Iron County. It occurs in decomposed limestone on the foot wall of an igneous dike, consists of black oxide of manganese (probably wad), iron oxide, and calcite, and contains silver, lead, and gold. The iron oxide is next to the dike, and the calcite is generally farthest away, next to the limestone, the manganese oxide being inclosed between them.

Iron ores high in manganese occur with metalliferous ores in the Tintic district, and are being used for flux in the local smelters.

NEVADA.

Manganiferous and ferruginous silver ores are found at Pioche, Lincoln County, Nev., and at Eureka.[c] Rhodochrosite occurs in association with quartz in the silver-bearing veins at Austin, Lander County,[d] and the tungstate of manganese, hübnerite, is reported from the Mammoth district,[c] Nye County.

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[a] Ray, L. A., Salt Lake City, personal communication.

[b] Bramel, W. H., Salt Lake City, personal communication.

[c] Penrose, R. A. F., jr., op. cit., p. 477.

[d] Idem, p. 476.

Beds of manganese ore occur at the foot of a range of basic eruptive masses in Boulder Canyon,[a] near Rioville, in the St. Thomas mining district, Lincoln County. The ore is rhodochrosite, partly altered to pyrolusite, and contains from 18 to 48 per cent of metallic manganese.

COMMERCIAL IMPORTANCE OF THE ORES.

The Great Basin region contains few manganese or manganiferous ore deposits of any value. The only ore produced has been a small amount of manganese ore at Golconda, Nev., and considerable manganiferous iron ore in the Tintic district, the latter being used for flux in the local smelters. In view of the fact that large portions of the Great Basin have not yet been thoroughly prospected, it is not unlikely that important deposits may still be found. The largest deposits known at present are those of the Tintic district and the still undeveloped deposits near Joy, Utah. The latter are more than 40 miles from the railroad, and until better transportation facilities are obtained will doubtless remain untouched. The Golconda deposits, while of interest geologically, are too small to be considered of commercial importance. The manganiferous ores of some of the precious-metal deposits, though present in considerable quantity, are used only for their content of silver, gold, or lead.

PACIFIC COAST REGION.

GENERAL STATEMENT.

The Pacific coast region includes the territory between the Sierra Nevada and Cascade Range on the east and the Pacific Ocean on the west. It is characterized by the absence of pre-Cambrian and early Paleozoic rocks, the oldest formations exposed being of Carboniferous age. The manganese ores of the region are confined to California and western Washington.

The characteristic occurrence of manganese in California is in the form of porous black oxide associated as layers and pockets with the jasper lenses of the Franciscan formation (Jurassic?) of the Coast Ranges. Smaller deposits are found in the Sierra Nevada in veins in the Calaveras (Carboniferous) formation, as fragments disseminated in auriferous gravels, or in deposits associated with igneous rocks.

Deposits of the first type are scattered through the Coast Ranges from Cape Mendocino on the north to the Channel Islands on the south. The principal occurrences so far known are in the Mount Diablo Range southeast of Livermore. This area has furnished nearly all of the ore mined in the State.

The deposits of the Sierra Nevada are small, and so far have been of no commercial importance.

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[a] Birkinbine, John, Mineral Resources U. S. for 1902, p. 141.

A ledge of manganese ore carrying 50 per cent manganese and 16 to 18 per cent silica is said to occur in the Olympic Mountains in western Washington.[a] Some authorities report it as being of low grade, but traceable for several miles.

LIVERMORE-TESLA DISTRICT.

GEOGRAPHY AND TOPOGRAPHY.

The Livermore-Tesla district is in the mountainous region southeast of Livermore, in Alameda, Santa Clara, and San Joaquin counties, Cal., about 45 miles east-southeast of San Francisco. It is approximately 35 miles long in a northwest-southeast direction and 15 miles wide. The district is in the Diablo Range, one of the largest divisions of the Coast Ranges. It is drained on the west by Arroyo del Valle and its tributary, Arroyo Mocho, Arroyo del Valle flowing into San Francisco Bay. The eastern part is drained by Corral Hollow Creek, La Puerta Creek, and Orestimba Creek, the waters of which flow into San Joaquin River and so to San Francisco Bay.

Topographically, the district consists of several parallel northwest-southeast ridges, including the Cedar Mountain Ridge, Crane Ridge, and others. They are separated by long, narrow, stream valleys. The range of elevations is from about 700 feet above sea level in the lower stream valleys to about 5,100 feet on the highest ridges. The slopes are steep, though rarely precipitous, and are generally covered with vegetation. The eastern part of the district is bare except for grasses and occasional live-oak trees, while in the western part there are large areas of brushwood, mainly chamiso and chaparral, interspersed with groves of oak, laurel, live oak, buckeye, cedar, and manzanita.

GEOLOGY.

The manganese deposits occur in jasper belonging to the Franciscan formation of probable Jurassic age. This formation consists of jasper lenses associated with a great thickness of sandstone, shale, and conglomerate. It is intruded by igneous rocks of different age and many varieties, among which are diorites, basalts, and peridotites. There are also associated with them metamorphic rocks, such as glaucophane and other schists and serpentine.

The Franciscan formation occupies by far the larger portion of the district. In the northeastern part around Tesla, however, there are coal-bearing rocks of probable Eocene age. The relations of this to the jasper is not known, nor whether Cretaceous rocks are present between them, as elsewhere in western California.

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[a] Swaney, Homer H., Pacific Steel Company, correspondence.

OCCURRENCE OF THE ORES.

The manganese ores occur in the jasper lenses of the Franciscan formation in the form of oxides supposed to be largely manganite and an associated impure oxide.[a] There are two principal types of deposits—(1) fault deposits and (2) interbedded lenses.

1. Fault deposits were found at only one locality, namely at the Old Ladd or Corral Hollow mine, about 5 miles southeast of Tesla in San Joaquin County.

2. Interbedded lenses of manganese ore occur in the jasper at many localities in the Livermore-Tesla district. They vary in extent up to 100 feet or more, and in thickness from a few inches to 5 feet or more, and consist mainly of black porous ore with abundant quartz seams. Deposits of this type have been prospected and exposed at the Black Jack, Bartlett, Fable, Isler (Eylar) Mountain, Homestead, Black Bear, Merchant, Pennsylvania, Black Wonder, and other mines, all of them southeast of Livermore, in Alameda, Santa Clara, and Stanislaus counties.

DESCRIPTIONS OF MINES AND DEPOSITS.

Old Ladd mine.—The workings at the old Ladd mine consist of a number of cuts and stopes. The deposit appears to be a filling of a fault fissure between walls of solid rock, and is exposed along the strike for several hundred yards, in which distance it varies considerably in thickness, but averages about 4 or 5 feet. It has a strike of about N. 80° W., and a dip varying from 45° S. to nearly vertical. Smaller veins branch off from the main fissure at low angles and continue for short distances in the wall rock. Recent openings consisting of an incline and stopes have been made about one-half mile from the main exposures in a direction a little north of west, on what appears to be an extension of the same deposit.

The north wall of the deposit at the old Ladd mine is formed by thin-bedded, greenish-gray jasper and shale, and the south wall by massive green, gray, or red jasper with no apparent bedding. (See fig 29.) The thin-bedded material is very much contorted, forming intricate patterns of faulting and folding, while the massive rock on the south wall is considerably fractured and contains stains and seams of manganese oxide. In some places these are so abundant as to form a breccia. The north wall contains very little manganese, the small amount present being in the form of little beads along cracks. Between the deposit and the north wall there is generally a layer of grayish-white kaolin.

The ore occurs (*a*) as an infiltration in and replacement of red and yellow clays along the fault fissure, (*b*) as a filling in cavities in these clays, and (*c*) in veins, as cement in breccias, and as replacements, in the wall rock. The ore is hard or soft according as it is associated with the jasper wall or with the clay.

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[a] Penrose, R. A. F., jr., op. cit., p. 481.

(*a*) The ore in the clay is bluish black, amorphous, and impure, and has a tendency to nodular forms, occurring frequently in kidneys or wormlike aggregates. It is generally soft and is mixed with considerable clay.

(*b*) The main mass of ore occurring along the fissure is hard amorphous or granular material, black or steel-gray in color. Some portions are entirely amorphous and break with conchoidal fracture; other portions are composed of a mixture of granular and amorphous material.

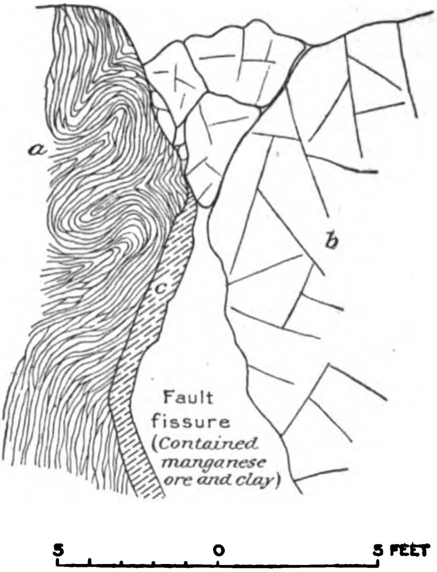

FIGURE 29.—Sketch showing the occurrence of manganese ore at the old Ladd mine, California. *a*, Thin-bedded chert; *b*, hard massive chert, with manganese seams; *c*, gray kaolin.

(*c*) The ore in the breccias and small veins in the jasper wall is very hard, with either amorphous or finely crystalline structure. The former generally has a steel-gray luster, and the latter is bluish.

Black Jack mine.—The Black Jack mine, on the Overacker property, is about 12 miles southeast of Livermoré, on the east side of Arroyo Mocho. The workings consist of a cut and several short tunnels. The country rock is jasper, thin layered and separated by seams of shale. The jasper layers differ in thickness from a fraction of an inch to several feet. The same layer varies in thickness, pinching out locally in many places. Most of the shale seams are thin. Both shale and jasper are greenish gray except where stained red or black by iron or manganese. The dip of the layers is about 35° W., the strike being a little east of north.

The ore occurs in several interbedded lenses or pockets a few feet thick and of small extent. It is a soft, friable black oxide contained in cavities between numerous intersecting quartz seams, or as seams intersecting jasper fragments. Most of the quartz seams are later infiltrations, but the fragments are residual from jasper, which the ore has replaced. The seams are generally vitreous and the fragments earthy. In some places yellow decomposed jasper fragments have been largely replaced by manganese oxide; elsewhere only a surface layer is replaced. The deposits commonly have a foot wall that is thin bedded and more shaly than the hanging wall.

Fable mine.—The Fable mine is about 26 miles southeast of Livermore in a small gulch just west of Arroyo Mocho. The workings consist of several cuts. The country rock is greenish-gray jasper with shale seams, but is heavily stained with manganese oxide adjacent to the ore. The principal deposit is in an irregular layer interbedded with iasper. (See fig. 30.) It varies in thickness from 6 inches to 3 or 4 feet and is 50 feet long or more. In the wider portions it has no distinct boundary, being largely made up of replacements in chert, elsewhere it has distinct hanging and foot walls. The dip of the rocks and of the deposit is 45° W., the strike being a little west of north. A smaller lens in a neighboring cut appears to be horizontal and to cut across the bedding.

The ore at both localities is soft black oxide and is largely a replacement of jasper, partly decomposed porous masses of which are abundant. The replacement has taken place inward from the surface and along cracks. Quartz seams are found in a network through the ore masses, while here and there are admixtures of red clay.

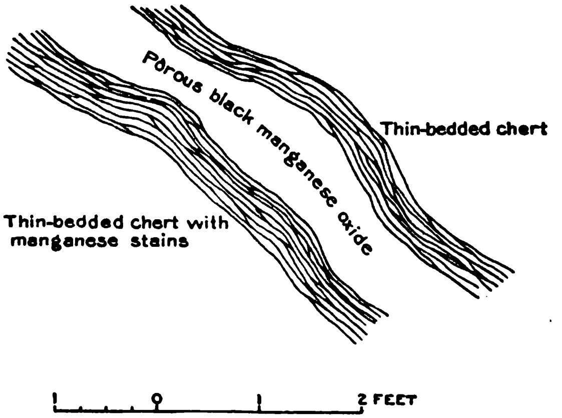
Porous black manganese oxide
Thin-bedded chert
Thin-bedded chert with manganese stains
0
1
2 FEET

FIGURE 30.—Section through the manganese deposit at the Fable mine, California.

Black Wonder group.—The Black Wonder group of manganese claims, owned by the California Manganese Mining Company of San Francisco, Howard A. Broughton, president, are on the border of Santa Clara and Stanislaus counties, about 40 miles southeast of Livermore. There are eight claims in the group, but the principal deposits occur on four of them.

The southern part of the area covered by the claims is greenish-gray sandstone of the Franciscan formation; the northern part is a mixture of jasper and fine shale interbedded. This jasper area is part of a larger area extending in a general east-west direction for 3 or 4 miles between the sandstone on the south and a large area of serpentine on the north. Where the principal manganese ore deposits occur the jasper-shale belt is about a mile wide. The manganese ores extend as discontinuous deposits along the jasper belt for more than a mile in a general northwest-southeast direction, the principal deposits being to the southeast and very near the sandstone contact.

The jasper-shale formation consists of beds and lenses of jasper interbedded with fine shale. The jasper may be thin bedded or very heavy bedded, in the latter case forming prominent outcrops. The beds generally strike in the direction of the main jasper belt, but the dips are exceedingly irregular.

The manganese ore occurs along heavy jasper beds as large masses replacing it, as veins, or merely as stains and partial replacements along cracks. The principal deposits—that is, those at the southeast end—are found along two or three prominent jasper beds 300 to 500 yards long, which are nearly parallel and 50 to 200 feet apart, separated by thin-bedded jasper and shale. Of these the deposits in the bed farthest south are most prominent. The ore in this bed is exposed in two tunnels, several surface workings, and numerous outcrops. In one of the tunnels a thickness of 7 or 8 feet of manganese ore, with irregular veins and bunches of jasper and quartz, is exposed, while in the other the thickness is 5 to 7 feet. At both of these places the hanging wall of the ore is thin-bedded jasper, and the foot wall gray shale. One outcrop between the two tunnels is 8 or 10 feet wide. Other smaller surface outcrops occur. No development work has been done in the other beds, and their extent is shown only by surface outcrops and float. Some of the ore is bluish-black, soft, and of very high grade, but the bulk is more or less mixed with jasper and quartz and will require concentration. The following analysis of the ore was kindly furnished the author by Mr. Broughton:

Analysis of manganese ore from Black Wonder mine, California.

Mn_2O_3	76.6
Iron oxide	2.27
Insoluble residue:	
SiO_2	10.8
Al_2O_3	1.2
MgO and CaO	.6
$CaCo_3$	3.7
Al_2O_3 (soluble in HCl)	.2
P	.1153
S	.2
H_2O	4.3
	100.1853

MINOR DEPOSITS IN CALIFORNIA.

Indications of manganese occur in the jasper lenses associated with sandstones and shales of the Franciscan formation in the Russian River valley in the western portion of the Coast Ranges, in Sonoma and Mendocino counties. Among these are the Cave mine, 10 miles northeast of Ukiah, and the Shaw mine, 8 miles northwest of Clover-dale. Workable deposits have not been found, the manganese oxides occurring merely as stains and small specks through the jasper.

Manganese has also been prospected on the east slope of the Coast Ranges in the northwestern part of Colusa County. The ore occurs as black oxide in jasper associated with shale on the eastern flanks of St. John Mountain[a] near the town of Little Stony.

The island of Red Rock,[b] in the northern part of San Francisco Bay, contains manganese ore in association with red jasper. The ore is hard and massive and has a steel-blue color and conchoidal fracture. It occurs along bedding planes and joint or fault planes in seams varying from mere films to a foot in thickness.

The mountains north of the Golden Gate in Marin County are composed largely of red shales and jasper. On the east slopes of these just west of Sausalito[c] there are manganese deposits associated with the red jaspers. Black manganese oxide stains the jasper and forms seams and small pockets in it locally, the latter ranging up to 3 feet in diameter.

Several deposits of manganese ore are found near the boundary of San Benito and Merced counties about 20 miles east of Tres Pinos.

In San Luis Obispo County small deposits of manganese are found in association with jasper lenses of the Franciscan ("San Luis") formation. The ore is black oxide and occurs as a coating of seams and as nearly pure masses replacing the jasper. The principal deposits are 5 miles west of San Luis Obispo and 8 miles west of Cayucos.[d] The ore west of San Luis Obispo is located on the summit of a small ridge about 1 mile south of Perfumo Canyon. Several trenches cut transversely across the ridge, and along them ore and manganese-stained jasper is exposed. The manganese ore occurs in pockets and as irregular replacements along jasper lenses. Masses of pure ore several feet in diameter are found, but in most places it is considerably mixed with partly replaced jasper. The jasper inclosing the ore is stained black by manganese oxide along cracks. Where fresh it is light brown, red, or yellow. Several tons of ore is on the dump.

Manganese occurs as pyrolusite and psilomelane in several veins, one of which is called the "Penrose lode," in the Calaveras formation 3 miles southwest of Meadow Valley, Plumas County.[e]

Two miles northeast of San Andreas,[f] Calaveras County, it is found as oxide in mica schists of the same formation. The principal occurrences are on Fortner's ranch, where the ore is found in small quartz lenses a few feet in width, running parallel to the schistosity of the inclosing mica schists. These quartz masses may be recrystallized jasper lenses or they may be later veins related to the gold-bearing quartz veins along the mother lode. Manganese ore is traceable in discontinuous pockets for 150 or 200 feet along the top of a ridge, and everywhere quartz accompanies it. At the best exposures ore is seen in irregular pockets a foot or two in diameter, which are subdivided into smaller pockets by a network of quartz veins, some of which are several inches in diameter. These smaller quartz veins are in turn stained with manganese along cracks, so there has evidently been a succession of depositions. Around the ore pockets the quartz is partly replaced by manganese oxide. The ore is bluish black in color and soft and friable.

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[a] Penrose, R. A. F., jr., Manganese: Its uses, ores, and deposits: Ann. Rept. Arkansas Geol. Survey for 1890, vol. 1, 1893, p. 490.

[b] Idem, p. 487.

[c] Idem, p. 489.

[d] Fairbanks, H. W., San Luis folio (No. 101), Geol. Atlas U. S., U. S. Geol. Survey, 1904.

[e] Turner, H. W., Bidwell Bar folio (No. 43), Geol. Atlas U. S., U. S. Geol. Survey, 1898.

[f] Turner, H. W., Jackson folio (No. 11), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

Indications of manganese are reported from the foot of Cape Horn bluff, near Colfax, Placer County.[a] The ore occurs here as black oxide in a network of thin veins from one-sixteenth to one-eighth inch in diameter in a series of slaty and schistose rocks.

Manganese ore has been found 2 miles north of Sonora,[b] Tuolumne County, as oxide and silicate in a deposit varying up to 12 feet in thickness at the contact of a green porphyry with a green schist. The schist is a chloritic, micaceous rock with laminated structure, while the porphyry consists of white feldspar crystals in a green matrix. Both rocks dip nearly vertically in the vicinity of the deposit, and strike east and west. The silicate (rhodonite) and oxide are either intimately mixed or in distinct masses blending into each other. The oxide always has the most exposed positions, however, and kernels of rhodonite are generally included in oxide masses. The rhodonite is pink and translucent with granular structure. The oxide is black and varies from hard, compact material to soft masses.

Small quantities of manganese ore occur embedded in auriferous gravels near Columbia,[c] Tuolumne County. The ore is in the form of kidneys of massive or granular black oxide. The underlying rocks are steeply dipping limestones and shales. Ore is found in them in a few places, principally as wad.

Several specimens of psilomelane obtained from the Maria Mountains in northeastern Riverside County were seen by the writer. The ore is said to occur as a network of small veins varying from 5 or 6 inches in diameter to mere stringers and covering many acres.

A deposit of high-grade manganese ore is said to occur in granite and schist 6 miles northeast of Elsinore, Riverside County.[d]

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[a] Aubury, L. E., Structural and industrial materials of California, p. 336; also Penrose, R. A. F., jr., op. cit., p. 495.

[b] Penrose, R. A. F., jr., op. cit., p. 492.

[c] Idem, p. 494.

[d] Aubury, L. E., loc. cit.

ANALYSES.

In the following tables are given analyses of manganite from the Corral Hollow mine and impure manganese oxide from Red Rock Island:

Analyses of manganese ores from the Coast Ranges.[a]

	Corral Hollow mine.	Red Rock Island.
MnO	75.26	44.21
O	6.94	7.31
Fe_2O_3	3.26	5.32
Al_2O_3	....	1.44
SiO_2	1.98	35.32
MgO	.56	....
CaO	3.10	....
BaO	None.	....
K_2O	.19	....
Na_2O	.58	....
H_2O	8.46	....
P_2O_5	....	.61
CoO	Trace.	....
	100.33	94.21
Mn	58.28	34.23
Fe	2.28	3.72
P	....	.27

[a] Penrose, R. A. F., Jr., op. cit., pp. 481–483.

ORIGIN OF MANGANESE ORES IN THE FRANCISCAN JASPERS.

The manganese ores in the Franciscan jaspers in their present form are clearly secondary concentrations, as is shown by their replacement of jasper and by the intimate association of manganese oxide and quartz veins, suggesting their contemporaneous deposition. That the jasper itself is the source of the ore is shown by the facts that it is invariably associated with the ore deposits throughout the Coast Ranges and that ores do not occur in the sandstones and shales of the formation. In the limited time at the writer's disposal it was not possible to go into a detailed study of the original form of the manganese and its method of concentration. It might be suggested, however, that they are intimately connected in origin with associated jasper. Lawson[a] discusses two ways in which the jasper might have been deposited—as deep-sea deposits or by siliceous springs. The theory that they are deep-sea deposits is discarded because of the associated sandstones and shales which were deposited in moderately shallow water. The presence of manganese oxide, which is very common in the deep sea, might well be accounted for by this theory if it were otherwise plausible.

Microscopic examination shows that but a small part of the mass of the jaspers consists of recognizable organic remains, and that the principal portion is probably a chemical precipitate. For this reason and on account of its local occurrence in lenses, Lawson suggests that the jasper had its principal source in local siliceous springs in the bottom of the ocean, and that small quantities of siliceous radiolarian remains became embedded in it as they dropped to the bottom.

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[a] Lawson, A. C., Geology of San Francisco Peninsula: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 424–426.

This hypothesis would also account for the presence of manganese in many of the chert lenses, because manganese in the form of bog ore is a very common spring deposit. Whatever the origin, however, it is certain that the jasper and manganese have been closely associated from the beginning. Whether the manganese was originally disseminated through the lenses and later concentrated into pockets by replacement of the jasper, or was partly in small pockets originally and was spread by replacement of the surrounding jasper, is a question that can only be solved by further detailed work.

COMMERCIAL IMPORTANCE OF THE ORES.

The manganese deposits associated with the Franciscan jaspers are very abundant throughout western California, but they are small and pockety. They vary in size from mere stains and small veins in the chert to pockets containing 10,000 or 15,000 tons. Locally, where structural conditions are favorable, larger deposits occur, as at the old Ladd or Corral Hollow mine.

The ore varies from soft and powdery to hard and compact. Both varieties may be quite pure or they may contain much silica in the form of quartz veins and unaltered chert.

The manganese deposits of the Sierra Nevada are small and scattered and, with the present means of transport, are of no commercial value. The new line of the Western Pacific Railway Company penetrates a district in which several deposits of high-grade ore occur, namely, those in the neighborhood of Meadow Valley; it is possible that in a few years ore may be shipped from these. Up to the present time all the ore shipped has been derived from the jasper deposits.

CHAPTER III.

FOREIGN MANGANESE DEPOSITS.

NORTH AMERICA.

CANADA.[a]

GENERAL STATEMENT.

Considerable quantities of manganese ore have been mined in New Brunswick and Nova Scotia and small amounts in Quebec and Ontario.

The ores of New Brunswick and Nova Scotia occur mainly in the lower Carboniferous limestone, but small quantities are found in both older and younger rocks. The principal deposits are located on or near the shores of the Bay of Fundy, or its eastern extremities, Minas Basin and Chignecto Bay, and smaller ones on the Atlantic coast of Nova Scotia and Cape Breton.

The following section shows the stratigraphy of the rocks of New Brunswick and Nova Scotia:[b]

Succession of rocks in New Brunswick and Nova Scotia.

Triassic red sandstones and traps.
Carboniferous:
  Upper coal formation; no productive coal beds.
  Middle coal formation; productive coal beds.
  "Millstone grit;" red and gray sandstone, shale and conglomerate.
  Carboniferous limestone; manganese deposits and gypsum.
Devonian quartzite and sandstone ("Lower Coal Measures" of Penrose; no productive coal beds).
Silurian, Ordovician, Cambrian, and pre-Cambrian.

The ores are pyrolusite, manganite, psilomelane, and wad. The first three of these are found together in the same deposits, while wad commonly occurs in separate deposits.

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[a] References on Canadian manganese-ore deposits:
Penrose, R. A. F., jr., Manganese: Its uses, ores, and deposits: Ann. Rept. Arkansas Geol. Survey, vol. 1, 1893, p. 496.
Denis, Theo., Manganese: Ann. Rept. Geol. Survey of Canada, vol. 15, 1902–3, Section of mines, E. D. Ingall, pp. 148s et seq.
Gilpin, E., Manganese ores of Nova Scotia: Trans. Roy. Soc. Canada, vol. 2.
Mineral Resources U. S. for 1885, pp. 350–356.
Idem for 1887, pp. 153–154.
Idem for 1888, pp. 133–136.
Idem for 1892, pp. 216–219.
Idem for 1893, p. 136.
Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 435–438.
Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, p. 206.
Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 311.
Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 6, 1900, pp. 144–145.

[b] Penrose, R. A. F., jr., op. cit., pp. 496 et seq. (revised).

Pyrolusite, manganite, and psilomelane occur in layers, lenses, and pockets along the bedding of the Carboniferous limestone, as veins in the brecciated portions, and as fragments in the surface clays derived from the limestone. The pyrolusite occurs in nests of fibrous orthorhombic prisms, many of them radiating from a center or encrusting masses of psilomelane. Some of the prisms are long and slender; others are short, even grading into granular aggregates. The manganite also occurs in prisms, but is markedly harder than pyrolusite. Psilomelane occurs in nodular masses of steel-gray or black color.

The following are analyses of Canadian pyrolusite and manganite:

Analyses of pyrolusite and manganite from Nova Scotia.[a]

	Pyrolusite (Amherst).	Manganite (Cheverie).
MnO_2	97.04	
Mn_2O_3		86.81
H_2O	.61	10.00
Gangue		1.14
Gangue and loss	2.35	
Iron oxide, barite and loss		2.05
	100.00	100.00

[a] Penrose, R. A. F., jr., op. cit., pp. 500–501.

Deposits of wad are much more abundant and widely distributed than those of the other minerals of manganese. They occur mainly in beds several feet thick near the surface, being derived from the decay of the underlying rocks. These are of various ages, but are more especially pre-Cambrian crystallines. The ore is of low grade and very siliceous, and the small quantities of it that have been mined have been used as pigment. It is porous and earthy, black or brown, and is commonly associated with limonite.

Analysis of wad from Boularderie Island, Cape Breton.[a]

MnO_2	44.33
Fe_2O_3	35.50
Insoluble	10.00
Mn	28.01
Fe	24.85

NEW BRUNSWICK.

The manganese deposits of New Brunswick occur throughout the southern part, in Kings, Albert, Westmoreland, and St. John counties, which comprise the area underlain by Carboniferous limestone.

Markhamville mine.—The most important deposit occurs at Markhamville, near Sussex, Kings County. The ore here is crystalline pyrolusite and manganite, with small amounts of psilomelane in some places. The deposits are in irregular pockets, or in flat lenticular layers in general following the bedding planes in the limestone. Veins of manganese oxides, many of them associated with calcite, cross the bedding of the limestone. At the surface the rock is decayed, forming a red residual clay in which are small bodies of ore derived from deposits originally in the limestone. The downward decomposition is more rapid along ore bodies than elsewhere. Decomposition has also gone on underground, forming subterranean caves and passages, and where these intersect ore bodies fragments of ore lie on the floors. While considerable ore has been procured from the last two sources, the bulk of the output has been derived from deposits in the limestone itself. The Markhamville mine has produced some ore of the highest grade known, much of the pyrolusite containing from 96½ to 98¾ per cent peroxide of manganese with only one-half of 1 per cent of silica and three-fourths of 1 per cent of iron. The large amount of available oxygen and the freedom from impurities have caused it to be highly prized by glass makers. The manganite is also of high grade and has been used for steel manufacture.

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[a] Penrose, R. A. F., jr., op. cit., p. 502.

The following table shows the composition of manganese ores from the Markhamville mine:

Analysis of manganese ore from Markhamville, New Brunswick.

	High-grade pyrolusite.[a]			Flux ore.[b]
	1.	2.	3.	
MnO_2	98.70	97.25	96.62	52.74
Fe_2O_3		.85	.78	3.75
Fe	.75			
SiO_2	.55			9.50
$CaCo_3$				13.40
Ba	Trace.			
BaO and SiO_2		.95	.85	
S				.02
H_2O		Trace.	Trace.	
Loss		.95	1.75	
	100.00	100.00	100.00	

[a] Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 436.
[b] Mineral Resources U. S. for 1885, p. 351.

Quaco Head mine.—The Quaco Head mine is situated on Quaco Head, a bold headland extending into the Bay of Fundy 1 mile south of St. Martins, St. John County. The ores occur in Carboniferous limestone and shale associated with a heavy conglomerate bed. The rocks dip steeply toward the bay, the conglomerate being the upper and the limestone the lower member, with the shale between. They are intruded by trap and unconformably overlain in places by Triassic red sandstone and conglomerate. These also contain some small nodules and seams of manganese ore. The ore in the limestone and shale is both crystalline and massive, the crystalline ore being chiefly pyrolusite and the massive ore psilomelane. There is also a porous honeycombed ore. The ore is in nodules and irregular veins in both the shale and the limestone, but in larger quantities in the shale.

The nodules are an inch to several inches in diameter, and the veins also vary in thickness. The following are analyses of ore from the Quaco Head mine:

Analysis of manganese ore from Quaco Head, New Brunswick.[a]

	Compact variety.	Porous variety.
MnO$_2$	71.54	65.00
Fe$_2$O$_3$	2.19	1.75
Ca	Trace.	Trace.
P	.02	.04
Insoluble silicate	8.37	6.66
Mn	58.20	57.15
Fe	1.53	1.23

[a] Penrose, R. A. F., jr., op. cit., p. 513.

Other deposits.—Smaller deposits of manganese ore occur in the following localities in New Brunswick: At the Glebe mine, 3 miles from Markhamville, in lower Carboniferous limestone; at Jordan Mountain, near Sussex, at the contact of the lower Carboniferous sediments and the pre-Cambrian crystalline rocks; at Shepody Mountain, at the contact of the lower Carboniferous conglomerates and pre-Cambrian chloritic slates; on the east side of Salisbury Bay, near the contact of lower Carboniferous rocks and Triassic sandstone; at Hopewell Corner, near the contact of the "Millstone grit" and lower Carboniferous rocks; at Hillsdale, in the lower Carboniferous rocks; at Petitcodiac, near the contact of lower Carboniferous limestone and gypsum; at Henry's Lake, in the lower Carboniferous rocks; at Tete à Gauche Falls, 8 miles from Bathurst, as nodules and veins in "Cambro-Silurian red and black slates," and as detached masses in residual material; between Quaco and Markhamville, in pre-Cambrian rocks; and in Goodland Mountain, Albert County.

A large deposit of wad, or bog ore, occurs in a homogeneous bed from a few inches to 30 feet thick near Hillsborough. The bed has been shown to have an average thickness of 6½ feet over an area of 17 or 18 acres. Other deposits of similar nature are found near Fredericton and at Queensbury, York County, and at Lincoln, Sunbury County.

The following is an analysis of wad from Hillsborough:

Analysis of wad from Hillsborough, New Brunswick.[a]

Mn	45.81
Fe	9.95
O	31.01
S	.03
P	.05
SiO$_2$	5.36
	92.21

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[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 311.

NOVA SCOTIA.

Distribution of ores.—Manganese ores are found in Nova Scotia on the shores of Minas Basin, on the Atlantic coast, and in Cape Breton. They occur as pyrolusite and as wad in rocks of all ages ranging from Carboniferous to pre-Cambrian. Only the pyrolusite has been mined to any extent. Manganiferous iron ores, carrying up to 14 per cent manganese, are found in different parts of the province. Most commonly the manganese deposits occur in the lower Carboniferous limestone, which is very characteristic and widespread, being found in Kings, Hants, Cumberland, Colchester, Pictou, and Antigonish counties, and in the four counties of the island of Cape Breton.

The lower Carboniferous limestone series consists of sandstone shale, grit, and limestone, with beds of gypsum and marl. In places they rest directly on pre-Carboniferous rocks; in other places they are separated from those rocks by the "Lower Coal Measures," or by beds of conglomerate.

In the northern part of Hants County, in the Minas Basin district, the Carboniferous marine limestone and the underlying Devonian sandstone and quartzite are found in a series of east and west folds, shifted and broken by transverse subordinate flexures. The presence of manganese in the upper of these divisions is first observable on the east at the mouth of Shubenacadie River, where a dark-colored limestone underlies the gypsum and is associated, a short distance east of the river, with red shales carrying veins of red hematite, manganese oxides, and calcite. The westward continuation of this horizon is noticeable at Tenny Cape, where a series of these measures, extending to Walton and Cheverie, about 15 miles, contains several beds of limestone, which apparently underlie the gypsum and bear manganese. The rocks dip steeply southward, away from the shore, and within a short distance the manganese-bearing beds disappear under the gypsum and other overlying beds, but reappear south of Windsor and at Douglas, 15 miles south of Tenny Cape, near the line of their junction with the pre-Carboniferous rocks. In this range of measures the manganese appears to be principally connected with a compact red and gray dolomite. At the western end of the district it occurs as veins in conglomerates and sandstones, and also in limestones in places where they are decidedly magnesian.

Tenny Cape mines.—The most important deposits of manganese in Nova Scotia are those of the Tenny Cape mines in Hants County, on the south shore of Minas Basin, midway between Noel and Walton. They were discovered in 1862, and have been worked intermittently since that date. The ores occur along the outcrop of the dolomitic limestone and shale layer, which dips steeply southward and is generally less than 300 feet thick. This layer is very much brecciated, being composed of small fragments closely packed together, with here and there large solid masses. It is underlain by a massive sandstone of Devonian age,[a] in some places separated from it by a layer of hard red clay, 2 to 4 inches thick, overlain by gypsum. The ore is found in the brecciated portions, between the fragments and surrounding them, and in the large solid masses along bedding planes and cross fractures. It occurs in the form of flat nodules, seams, and pockets, the last either isolated or connected by thin seams of ore. The seams vary in thickness from 1 to 6 inches, and the pockets from 1 inch to several feet. Some of the pockets are reported to have produced 300 tons of ore.

The ore is chiefly high-grade fibrous pyrolusite, associated with psilomelane. Manganite occurs in small quantities and has a compact and partly fibrous structure. In some places, calcite, selenite, barite, and limonite are found in considerable quantities with the ore; at other places the ore is free from gangue.

Cheverie mine.—West of the Tenny Cape mine, near Cheverie on Minas Basin, is the Cheverie mine.

The ore at this locality is a black crystalline mixture of pyrolusite and manganite associated with calcite in a network of small veins from one-eighth inch to 4 inches thick, in a breccia composed of fragments of massive and shaly limestone. It commonly encircles fragments or penetrates along the bedding planes of unbroken fragments. Much of the calcite occurs in long crystals at right angles to the vein walls, the manganese filling the center.

The following are analyses of manganese ore from Tenny Cape:[b]

Analyses of manganese ore from Cheverie and Douglas mines, Tenny Cape, Nova Scotia.

	Douglas.	Cheverie.
Mn_2O_3	84.620	90.15
Fe_2O_3	.603	2.55
O	7.035	....
P_2O_5	....	1.029
BaO	.724	1.12
CaO	....	Trace.
H_2O+	3.63	....
Moisture	1.66	2.05
Insoluble	1.728	2.80
	100.00	99.699
Mn	53.47	56.97
Fe	.42	1.78
P	....	.45

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[a] Denis, Theo., op. cit., p. 1555.

[b] Penrose, R. A. F., jr., op. cit., pp. 522, 524; also Mineral Resources U. S. for 1885, p. 353.

Analyses of manganite from Tenny Cape, Nova Scotia.

	Tenny Cape.	Cheverie.
Mn_2O_3	85.54	86.81
Fe_2O_3	1.18	2.05
BaO	.89	....
P_2O_5	.34	....
H_2O	8.54	10.00
Insoluble	3.27	1.14
	99.76	100.00
Mn	....	60.42
O	51.54	....

Other deposits in Minas Basin region.—Other deposits in the Carboniferous limestone in this vicinity are at the Parker mine, which is three-fourths of a mile northwest of Tenny Cape and shows the same type of ore as the latter; at the Moose Brook mine, 4 miles northeast of Tenny Cape; at the Walton mine and other localities near Walton, where the ore occurs as manganite and pyrolusite associated with barite in a breccia similar to that at Cheverie; near Windsor, in veins and pockets in limestone and sandstone; and at Noel, Douglas, and Rawdon.

Other deposits in northern counties.—Lower Carboniferous limestones at Minudie and Amherst, Cumberland County, have yielded small quantities of a soft fine-grained pyrolusite, that from Minudie showing on analysis 97.04 per cent of manganese peroxide. Ores similar to those of Tenny Cape are found at Onslow and on Salmon River near Truro, Colchester County, the latter yielding 92 to 95 per cent manganese peroxide. In these localities there are red shales and sandstones and beds of dark bluish limestone, covered by beds of gravel and clay, which contain nodules of granular pyrolusite. The ore also occurs in veins up to 4 inches in thickness in the sandstones, and in irregular nests and layers in the limestone. Calcite, barite, and selenite are found as gangue in the veins, the manganese occurring as fibrous oxide. Near Glengarry station, in Pictou County, nodules of fibrous pyrolusite, containing 84 per cent peroxide of manganese, are found with calcite in the dark-blue limestone near its junction with the pre-Carboniferous rocks. Bowlders of a mixture of psilomelane and manganite occur at Springville, Pictou County, lying on the dark limestone and on the associated red shales.

Cape Breton Island.—In Cape Breton Island ores are found in the mountainous district between the Atlantic coast and Bras d'Or Lake The country rock consists of felsite overlain by a basal conglomerate and a series of shales and grits, which are in turn overlain by limestone. All are of lower Carboniferous age, and are overlain by "Millstone grit." Locally the limestone and shales are absent and the "Millstone grit" lies directly on the basal conglomerate. The manganese ore occurs in beds associated with limestone and red shale, which dip at angles varying between 25° and 32°. The rocks here are compact and not shattered as those of the Minas Basin district.

The only deposit of economic importance on the island is at the Moseley iron mine, near the head of Loch Lomond, in the western part of Cape Breton County. The ore is found in both crystalline and massive forms, part of it being pyrolusite, part manganite. Associated with it as gangue are barite, calcite, and selenite. It occurs as nodules, pockets, and interbedded layers in limestone and in overlying arenaceous soft red shale, being most abundant in the latter. In some places it impregnates a coarse conglomerate that overlies the red shale. The ore layers vary up to 18 inches in thickness, and at many places are connected by cross stringers.

A short distance southeast of the main mine manganese ore occurs as a bed underlying a dark limestone layer in a formation consisting of red and green shale, with coarse grits. The limestone and ore have an average thickness of 8 inches.

The ores from the Moseley mine contain about 88.9 per cent manganese peroxide with 2 per cent ferric oxide.

Deposits outside of Carboniferous areas.—Small manganese deposits are found in many places in Nova Scotia outside of the Carboniferous areas. Near Mount Uniacke, between Halifax and Windsor, manganese ore is found in small pockets and veins penetrating granite. It also occurs in the quartzites of the auriferous lower Cambrian of the Atlantic coast; in veinlets in the granites of Musquodoboit; as small irregular seams in the granite of Ship Harbor; and in quartzites and slates of Devonian age in the hills south of Wolfville, in Kings County. In the Triassic sandstone of Kings County manganese ore occurs in the bedded form near Cornwallis and Wolfville, and in the Triassic trap it is said to line cavities in association with zeolites.

Wad is found in superficial deposits in many localities in Nova Scotia. Among them are Jeddore, Ship Harbor, St. Margarets Bay, Shelburne, La Have, Chester, Parrsborough, Springhill, and Pictou and Antigonish counties.

Manganiferous iron ores occur in several localities in Nova Scotia, especially in Pictou, Colchester and Antigonish counties.

At several localities near Springville, Pictou County, limonite ores, found along the junction of the lower Carboniferous and pre-Carboniferous rocks, are heavily charged with manganese. The ore is dull brownish in color and softer than ordinary limonite. In Antigonish County similar ferriferous manganese ores have been found in the drift at several localities.

At the Londonderry iron mines, Colchester County, in a great vein of brown hematite, associated with ocher, ankerite, sideroplesite, and calcite, in strata of "Lower Silurian age," secondary changes have locally enriched the deposit with manganese peroxide up to 14 per cent. Some of the manganese is present as manganite in incrusting fibers and some is present as wad.

Analyses.—The following are analyses of manganiferous iron ore from Nova Scotia:

Analyses of ferriferous manganese ores from Springville, Nova Scotia.[a]

	1.	2.
MnO_2		14.41
Mn_2O_3	62.95	
Fe_2O_3	10.848	48.223
Al_2O_3	2.88	.015
CaO	7.28	.015
MgO	1.63	
BaO	.67	
S		.48
P		.02
H_2O+		12.53
Moisture	1.45	
Insoluble	2.731	25.13
	90.439	100.823
Mn	43.810	9.106
Fe	7.594	33.756

[a] Mineral Resources U. S. for 1885, p. 354.

Analysis of ferriferous wad from Londonderry, Nova Scotia.

MnO_2	67.10
MnO	10.67
H_2O	9.37
CuO	.88
FeO	4.09
Al_2O_3	.67
Ni and CO oxides	.65
CaO	2.49
MgO	Trace.
SiO_2	4.08
	100.00

OTHER CANADIAN DEPOSITS.

A few deposits of manganese occur in Canada outside of Nova Scotia and New Brunswick. On Amherst Island of the Magdalen group, in the Gulf of St. Lawrence, manganese ores occur associated with sandstone, shale, gypsum, and doloritic rocks of lower Carboniferous age. The ore is principally crystalline manganite, containing 45.61 per cent peroxide, but pyrolusite occurs in it. It is found in loose blocks in débris at the foot of a cliff.

In the "eastern townships" in Quebec manganiferous dolomites are found in the metamorphic rocks. They contain manganese up to 8 per cent and in many places are stained brownish at the surface, owing to its oxidation. Small deposits of bog manganese occur locally.

At Bachewanung Bay, on Lake Superior, manganese has been found in stringers in a reddish trappean rock, with quartz, calcite, and fluorspar. The ore, which is massive with small geodes of crystals, contains 60 per cent peroxide of manganese and is described as manganite.

Small quantities of manganese oxide are said to occur in some of the iron-ore deposits in the Gunflint Lake district in western Ontario.

In the Nastapoka chain of islands on the east coast of Hudson Bay carbonate of manganese is reported to occur in association with spathic iron ore. The ores yield about 25 per cent metallic iron and 24 per cent carbonate of manganese.

Little is known of the manganese deposits of western Canada, but no deposits of importance have been reported.

NEWFOUNDLAND.[a]

In Newfoundland manganese carbonate of brownish color occurs, interbedded with slates "of probable Silurian age," at Placentia Bay. It is partly oxidized in places and is reported to have the following composition:

Analysis of manganese carbonate from Newfoundland.

$MnCo_3$	84.6
SiO_2	14.4
FeO, CaO, and MgO	Traces.

CUBA.[b]

SITUATION OF DEPOSITS.

Manganese deposits of considerable importance occur in the southeastern part of Cuba, in the province of Santiago de Cuba. The manganese-bearing area is located in the valleys of Cauto and Guantanamo rivers and on the north flanks of the Sierra Maestra the summits of which rise above it on the south to a height of 7,670 feet above sea level. It extends from Guantanamo on the east to Manzanillo on the west. The following description of the district is taken largely from an article by Spencer:[c]

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[a] Hunt, T. Sterry, Geological survey of Canada, 1879-80, p. 106.

[b] References on Cuban manganese-ore deposits:

Spencer, A. C., Manganese deposits of Santiago, Cuba: Bull. U. S. Geol. Survey No. 213, 1903, p. 251.
Spencer, A. C., The manganese deposits of Santiago Province, Cuba (illustrated): Eng. and Min. Jour., August 23, 1902, p. 247.
Souder, Harrison, Mineral deposits of Santiago, Cuba: Trans. Am. Inst. Min. Eng., vol. 35, 1904, p. 308.
Brown, H. C., Mineral resources of Cuba in 1901, p. 24.
Hayes, C. W., Vaughan, T. W., and Spencer, A. C., A geological reconnaissance of Cuba, 1901, p. 62.
Mineral Resources U. S. for 1888, p. 137.
Mineral Resources U. S. for 1891, p. 142.
Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 312.
Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, 1899, p. 146.
Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 6, 1900, p. 146.
Mineral Resources U. S. for 1902, p. 147.

[c] Spencer, A. C., Manganese deposits of Santiago, Cuba: Bull. U. S. Geol. Survey No. 213, 1903, p. 251.

The rocks of this region form an east and west synclinal basin. Those exposed on the crests of the Sierra Maestra dip to the north and consist of coarse well-stratified volcanic breccias. They pass, on the north slope, beneath alternating strata of marine sediments and fine-grained volcanic tuff, which are in turn covered by basalt flows and still other fragmental volcanic rocks. This essentially volcanic series grades upward into and finally gives place to limestone and other marine sediments.

The ore is chiefly pyrolusite, but other oxides of manganese occur. The principal deposits comprise three groups of mines—the Ponupo group, the Boston mines, and the Ysabellita group—located east of Cristo, a town on the Sabanillo and Maroto Railroad, about 11 miles northeast of Santiago. Smaller deposits are found at several places south of Cristo and at Dos Bocas.

PONUPO, BOSTON, AND YSABELLITA MINES.

The Ponupo, Boston, and Ysabellita groups of mines are located on the crests of small anticlines of sedimentary rocks, well within the general synclinal basin above mentioned.

The Boston and Ysabellita mines are 3 and 4 miles, respectively, east of Cristo, and the Ponupo mines, which are the most important in the district, are 12 miles northeast. Ponupo is the terminal of the Ponupo branch of the Sabanillo and Maroto Railroad, which leaves the main line a short distance north of Cristo. It consists of seven mines, of which the Vencedora and Sultana are the most important.

The Boston and Ysabellita mines are supposed to be on the same anticlinal arch, and the Ponupo mines are on another anticline, the relation of which to the first is not known. The ores are associated with jasper masses in green sandstone. According to Spencer there is good reason to believe that all these mines are at the same stratigraphic horizon. A limestone band composed of Foraminifera of the type *Orbitoides* lies just above the ore-bearing bed at each of these localities, and the ore is found in a loose, disintegrated, dark-green sandstone of exactly the same nature in each place. Where the sandstone has been exposed at some distance from the ore bodies, as at the Boston mines, it is found to be composed largely of shells of a large species of Foraminifera, filled with glauconite. Near the ore bodies the calcareous shells are not seen.

Large masses of jasper occur at the Boston and Ysabellita, as well as the Ponupo mines. At the Boston mine masses of jasper are entirely surrounded by ore. At the Ponupo mines there is high-grade ore at the contact of the jasper and decomposed rock and low-grade ore mixed with rock farther away. Here the ore has also partly replaced the foraminiferal limestone above the ore-bearing bed. The jasper, generally red or yellow, is in irregular masses forming knolls, on which the mines are located, and the ore is in equally irregular pockets associated with them. Locally streaks and veins of jasper penetrate the ore in all directions, and in such places it is valueless. Generally, however, the ore is found in nodules easily separated from the matrix.

DEPOSITS SOUTH OF CRISTO AND AT DOS BOCAS.

The deposits south of Cristo and at Dos Bocas are in the mixed volcanic and sedimentary series on the south arm of the syncline, where the rocks dip at various angles to the north. Although these strata are at a different horizon geologically, the relations of ore, jasper, and country rock are the same in these mines as in the deposits east and northeast of Cristo.

The deposits are associated with lenses of jasper in a disintegrated green rock with red spots. The original nature of the green rock is not known, but it is possibly the alteration of a green sand or glauconite formation. The jasper masses vary from a few inches to 15 or 20 feet in thickness, and in some places have a lateral extent of several hundred feet along the bedding. They are very irregular and follow the bedding only in a general way.

The ore occurs (1) filling spaces between the jasper and the country rock, (2) in veins in the jasper, and (3) disseminated through the country rock adjacent to jasper masses. In the last position the ore commonly has the form of nodules arranged along the bedding planes of the decomposed rock which it has partly replaced. The relation of the ore and jasper is very intimate, minute veins of ore penetrating the jasper, and siliceous veins similarly penetrating the ore. This suggests a contemporaneous secondary origin of ore and jasper after the deposition of the country rock.

OTHER DEPOSITS.

Besides the San Luis district, which includes the Ponupo, Boston, and Ysabellita mines and the mines south of Cristo and near Dos Bocas, several other localities in southeastern Cuba have manganese deposits which may become important commercially. These include the Majuba Hill district, about 21 miles northwest of Santiago; the Los Negros district, about 75 miles west-northwest of Santiago; the Bueycito district, about 42 miles east of Manzanillo; the Portillo district, near Portillo, on the south coast; and the Macio district, between Guama and Santiago de Cuba.

Very little exploration work has been done in these localities, but the ore found up to the present has been chiefly in the form of surface fragments and small scattered deposits.

ANALYSES.

The following are analyses of Cuban manganese ores:

Analyses of manganese ore from the Ponupo mines. Cuba.[a]

Source of sample.	Mn.	P.	Fe.	SiO₂.
Vencedora, north side	49.19	0.062	2.42	2.72
Do	51.91	.049	.79	1.09
Do	50.51	.057	.52	1.33
Vencedora, big pit	51.79	.063	.99	1.30
Vencedora, pit back of kitchen	51.12	.033	.98	1.17
Sultana, top of bank	51.36	.070	.79	1.22
Sultana, river bank	44.63	.038	1.77	6.11
Volcanis	48.22	.063	4.39	3.00

[a] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, 1899, p. 140.

Cargo analyses of Cuban manganese ore.[a]

	1.	2.
Mn	47	53
SiO_2	4	9
P	.03	.10

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 312.

Analyses of manganese ore from the Boston mines, Cuba.[a]

	1.	2.	3.
Mn	50	54.025	56.88
Fe	1-3	1.64	.30
P		.059	.030
S			.005
SiO_2		5.40	.810
Al_2O_3		1.911	
BaO		1.105	
Moisture		.60	2.00

[a] No. 1 is from Mineral Resources U. S. for 1902, p. 147; Nos. 2 and 3 from Souder, Harrison, op. cit., p. 312.

OTHER WEST INDIES.

A bed of manganese ore of superior quality is reported from the island of St. Martin in the West Indies, and another deposit has recently been discovered in Haiti.

MEXICO.[a]

Manganese ore has not been mined to any extent in Mexico. Few, if any, of the iron-ore deposits have associated manganese, though veins containing pure manganese ore are found at various localities. Veins of pyrolusite, psilomelane, and wad are found in the Cretaceous limestones in the districts of Acatlan and Tepexi, in the southern part of Puebla. Irregular veins of psilomelane occur in the Cretaceous limestones in Sierrita de Metoche, near Coxcatlan, Guerrero. Manganese sulphide, alabandite, accompanies the silver-lead minerals of Sierrita de Tepeyahualco, Puebla. Manganese silicate and oxides accompany the minerals of some of the silver veins, the former being found in the unoxidized portion and the latter in the upper oxidized zone. The carbonate, rhodochrosite, is found in the intermediate zone. There are veins of this mineral at Pachua and Real del Monta, Hildalgo, and in the deposits of Tetela del Oro, Puebla.

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[a] References on Mexican manganese-ore deposits:

Aguilera, José G., The geographical and geological distribution of the mineral deposits of Mexico: Trans. Am. Inst. Min. Eng., vol. 32, 1902, p. 505.

Biddle, C., Notes from Magdalena Bay, Mexico: Eng. and Min. Jour., vol. 82, p. 361.

Manganese ore is also reported from Margarita Island, Magdalena Bay,[a] on the west coast of Lower California.

PANAMA.[b]

The Nombre de Dios manganese-bearing region of Panama covers an area of nearly 300 square miles along the Caribbean Sea, beginning near Porto Bello and extending eastward for 35 miles. All the ore is found on the east slopes of the Cordilleras at a maximum distance of 10 miles from the coast. It occurs on the lowlands near the sea, as well as on the slopes and tops of the ridges. One deposit, the Culebra, is on an island a short distance from the coast. The ore is shipped from the port of Nombre de Dios. The following six mines have shipped ore from the district: Viento Frio, Carano, Concepcion, Soledad, La Guaca, and Culebra. The ore occurs in pockets in clay, which is generally yellow at the surface and bright red where associated with ores, though all shades from red to white occur. The rocks immediately associated with the manganese deposits are of sedimentary origin, probably originally shales, but so greatly altered as to leave their original character doubtful. Near some of the deposits they have been metamorphosed into jasper and thus preserved. The underlying rock is reported to be serpentine.

The ores occur as oxides, principally psilomelane, but also pyrolusite and braunite. Pyrolusite and psilomelane are intimately mixed, blending into each other. Pyrolusite fills many cavities in the psilomelane and commonly occurs in radiating crystals on a base of psilomelane.

Where the clay is worn away the pockets or masses of ore stick above the ground like bowlders. They vary from a few pounds to 500 tons in weight, and one mass has been found from which 1,000 tons of good ore were taken. Not all bowlders are pure ore, but many contain ore-bearing rock.

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[a] Biddle, C., loc. cit.

[b] References on manganese-ore deposits of Panama:

Chibias, E. J., Manganese deposits of the department of Panama, Republic of Columbia: Trans. Am. Inst. Min. Eng., vol. 27, 1897, p. 63.

Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 313.

Mineral Resources U. S. for 1902, p. 147.

The first shipments from the region were made in 1871, from the village of Viento Frio. The early mining was primitive, consisting of breaking up the surface bowlders near the sea and packing the ore to the coast upon men's backs.

The following are complete analyses of ore from Panama:

Analysis of pure ore from the Soledad mine, Panama.[a]

MnO	78.25
O	11.83
CuO	.67
SiO_2	2.00
SiO_2 (soluble)	2.67
Fe_2O_3	.40
Al_2O_3	.21
CaO	1.32
MgO	.16
K_2O	.10
Na_2O	.38
H_2O	1.70
P_2O_5	.03
	99.72
Mn	60.60

Analysis of average ore from La Guaca mine, Panama.[b]

MnO_2	16.98
Mn_2O_3	59.30
CuO	.09
SiO_2	18.77
Fe_2O_3	.90
Al_2O_3	.12
CaO	.98
MgO	.30
SO_2	.10
H_2O	3.02
P	.031

The following are other analyses of manganese ore from Panama:

Cargo analyses of Panama manganese ore.[c]

	1.	2.	3.	4.	5.
Mn	53	47.5	57.502	56.788	54.561
SiO_2	13	20	4.18	5.82	9.88
H_2O	....	....	2.734	1.415	5.372
Phos	....	....	.054	....	....

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[a] Mineral Resources U. S. for 1902, p. 149.

[b] Chibias, E. J., loc. cit.

[c] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 314.

Analyses of picked samples from Nispero, Panama.[a]

	1.	2.	3.	4.
Mn	63.74	62.92	62.76	59.98
Fe_2O_3	.28	1.13	.98	1.19
SiO_2	.25	.39	5.42	4.71

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 314.

SOUTH AMERICA.

BRAZIL.[a]

Manganese ores are widely distributed in Brazil. Large deposits occur in the Miguel Burnier, Ouro Preto, and Lafayette or Queluz districts, in the State of Minas Geraes, and smaller deposits in the Nazareth district, in the State of Bahia. Ores are also reported from the States of Matto Grosso, Parana, and Santa Catharina, and from the region of Amazon River.

NAZARETH DISTRICT.

Situation.—The Nazareth district is about 16 miles west of Nazareth, a town which is on tide water about 30 miles west of Bahia and is reached by a steamer from that city by way of Jaguaripa River. Ore has been shipped from two mines situated close together, the principal one being the Pedras Pretas. The Nazareth-Amargosa Railway, running west from Nazareth, passes within half a mile of the mines.

Geology.—The substance of the following description of the geology of the district is from the article by Branner.[a]

The city of Bahia stands upon crystalline schists cut by eruptive dikes. Immediately west of the city is a Cretaceous basin that extends westward almost within a mile of Nazareth, where the crystalline rocks again appear. At Nazareth the schists are so decomposed that solid rocks are to be seen in places only in the stream beds and here and there in the hills. It is in these decomposed rocks that the manganese is found at the Pedras Pretas mine, 16 miles farther west.

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[a] References on Brazilian manganese-ore deposits:
Branner, J. C., The manganese deposits of Bahia and Minas, Brazil: Trans. Am. Inst. Min. Eng., vol. 29, 1899, p. 756.
Scott, H. K., The manganese ores of Brazil: Jour. Iron and Steel Inst., No. 1, 1900, p. 179.
Derby, O. A., On the manganese ore deposits of the Queluz (Lafayette) district, Minas Geraes: Am. Jour. Sci., July, 1901, p. 18.
Derby, O. A., On the original type of manganese-ore deposits of the Queluz district, Brazil: Am. Jour. Sci., March, 1908, p. 213.
Katzer, Ein eigentümliches Manganerz des Amazonasgebietes: Österr. Zeitschr. für Berg- und Hüttenwesen, vol. 46, 1898, pp. 41-46.
Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, pt. 1, pp. 254-255 and 263.
Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, 1899, p. 140.
Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 6, 1900, p. 149.
Mineral Resources U. S. for 1900, p. 128.
Mineral Resources U. S. for 1901, p. 140.
Mineral Resources U. S. for 1902, p. 150.
Mineral Resources U. S. for 1905, p. 98.

In neighboring States granites and gneisses are associated with the schists. Nothing definite is known as to their age, but farther north rocks believed to be of Paleozoic age rest upon them unconformably.

The country in which the manganese mines are situated is the comparatively low, hilly, densely forested coastal region of eastern Brazil.

Ore deposits.—The Pedras Pretas mine is in soft earth, except where large masses of solid ore have been drifted into. Most of the ore thus far shipped has come from a great horizontal sheet that spreads out almost on the surface of the ground. (See fig. 31.) Underneath this, and connecting with it, is a sheet or vein standing at an angle of 60° and varying in thickness from 1 to 33 feet. It seems evident that the horizontal surface sheet is the accumulation from the breaking up and weathering out of the ore in the underlying bed and the removal of the clays about it.

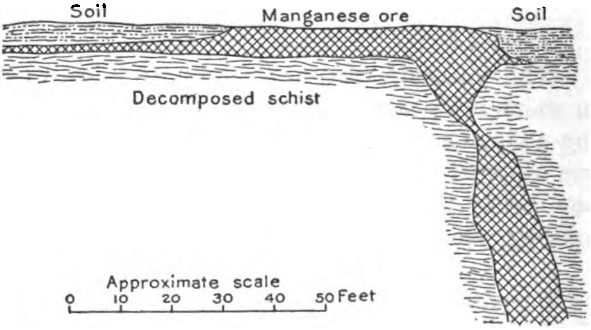

FIGURE 31.—Section through the ore body of the Pedras Pretas mine, Brazil. (After Branner.)

The ore is psilomelane, occurring as lumps and large masses in the above-described beds. Some of the lumps are botryoidal in form, but most of them are angular. Many are more than 2 feet in diameter, the smallest ones shipped being about the size of a fist. Frequently masses are taken from the mines that weigh a ton and a half.

MINAS GERAES DISTRICTS.

GEOGRAPHY AND GEOLOGY.

The existence of manganese ores was discovered in the Miguel Burnier in 1888, and mining was begun at Usina Wigg in 1894. Active exploration of the surrounding territory, however, was not started until 1897. The following descriptions are condensed largely from the articles by Scott and Derby (cited on p. 183).

The deposits are situated along the main line of the Central Railway system northward from Lafayette to the point where the branch line to Ouro Preto turns off to the east, and along this branch line nearly to Ouro Preto.

Lafayette is about 283 miles north of Rio Janeiro. The region along the branch line is very mountainous and is divided into the Miguel Burnier and Ouro Preto districts; the deposits north of Lafayette are in a gently undulating country known as the Lafayette district. Each of the districts is characterized by a different type of deposits.

According to Scott,[a] the ancient crystalline rocks of Brazil are divided into two great series. The oldest is composed of various kinds of gneiss, which are frequently granitoid in texture, and which, with the massive granites and diorites injected into them, give the characteristic topographic features of needles and domes to the mountains formed by them. The second division is composed of a series of schistose quartzites, micaceous schists, and limestones and produces the characteristic jagged topographic features of monoclinal peaks and ridges. It has come to be known as the Itacolumite series from a name given to its quartzitic members.

Intermediate in character and position between these two divisions, and perhaps constituting a third division, is a considerable body of true mica schists, of doubtful geologic relations because, in appearance at least, they shade off into the true gneisses on the one side and the micaceous schists or phyllites of the Itacolumite series on the other. All these rocks are cut by dikes and bosses of granite, syenite, diorite, diabase, and perhaps other types of eruptive rocks. The first three are more abundant in and characteristic of the gneissic division.

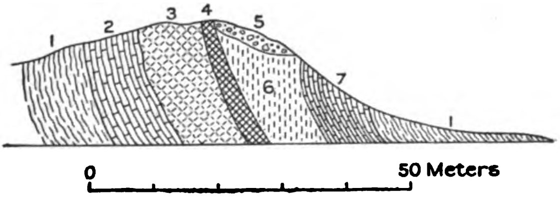

FIGURE 32.—Typical section of the manganese-bearing series, Miguel Burnier, Brazil. (After Scott.) 1, Micaceous schists; 2, white limestone; 3, impure earthy ores of iron and manganese; 4, manganese ore; 5, iron-ore conglomerate or Canga; 6, Jacutinga or Itabirite formation; 7, gray limestone.

MIGUEL BURNIER DISTRICT.

Occurrence of the ores.—The Miguel Burnier deposits occur in a bed in the Itacolumite series. A typical section of the manganese-bearing series is shown in figure 32. The micaceous schists are the most important rocks of the district. They are of great thickness and much decomposed. The white limestone is about 33 feet thick. It is dolomitic and contains some iron and manganese and a very small amount of siliceous residue. The earthy iron and manganese ore bed is about 80 feet thick, including a manganiferous iron-ore stratum above and another below, varying in content of manganese oxides up to 20 per cent, and in ferric oxide up to 72 per cent. The upper iron-ore bed is micaceous. Between the iron-ore strata there are siliceous layers containing ferric oxide varying up to 15 per cent and a slight amount of manganese oxide, baryta, and alumina. The strata are dark colored or reddish and earthy, and above them is the manganese-ore bed.

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[a] Scott, H. K., op. cit., pp. 179 et seq.

This bed varies greatly in thickness, but probably has an average of about 7 feet. It is composed mainly of dark metallic ore showing bedding and interstratified with softer and hydrated ore. The hard ore makes up, on the average, 80 per cent of the bed and is generally in lenses or irregular blocks.

The Itabirite or Jacutinga formation consists of thin layers of fine quartz sand and micaceous iron ore in alternate bands. It varies from 65 to 130 feet in thickness and is generally much decomposed.

The gray limestone is dolomitic like the white limestone and contains iron and manganese, but has a much larger siliceous residue. It has about the same thickness as the white limestone.

The Canga or iron-ore conglomerate is a surface deposit on the Itabirite bed, consisting of broken fragments of iron ore recemented by limonite. Where free from quartz it is excellent iron ore.

The principal mines operating the manganese bed described above are the Miguel Burnier, Usina Wigg, and Bocania.

Analyses.—The following are analyses of ore from the Miguel Burnier district:

Analyses of two cargoes of manganese ore, Usina Wigg mine, Brazil.[a]

	1.	2.
SiO_2	0.53	1.25
MnO_2	80.62	79.40
MnO	5.47	6.23
Al_2O_3	2.21	1.45
Fe_2O_3	2.50	4.03
BaO	2.30	1.90
CaO	.70	Trace.
MgO	1.05	.05
P_2O_5	.07	.048
SO_3	Trace.	.065
Arsenic acid	None.	.034
CO_2	None.	None.
K_2O and Na_2O	Trace.	.55
H_2O	4.95	4.74
	100.30	99.757
Mn	55.14	55.02
P	.03	.021

[a] Scott, H. K., op. cit.

Average analyses of manganese ore from Miguel Burnier district, Brazil.[a]

	Usina Wigg.	Miguel Burnier.
Mn	50-54	47-51
SiO_2	1- 2	1- 2
P	.01-.03	.02-.04
Moisture	15-20	15-20

[a] Mineral Resources U. S. for 1901, p. 142.

OURO PRETO DISTRICT.

Occurrence of the ores.—The deposits west of Ouro Preto are in the same rock series as the ores of the Miguel Burnier region to the west, but their occurrence is different. The manganese ore is found in two distinct states:

(1) Crystallized ore occurs with the Jacutinga formation and is probably derived by denudation of the manganese bed beneath it and its subsequent recrystallization in superficial clays. It does not generally lie in well-defined beds, but is scattered over great areas.

(2) Hydrated ore is found as binding material in conglomerate masses of broken-down Jacutinga. The surface ore is of good grade, but the deeper ore is very siliceous. It contains an appreciable amount of nickel and cobalt, which give it a greenish appearance.

Properties containing these classes of ore are the Rodeio, Rodrigo Silva, Renera, and Gandarella, and some in the vicinity of Miguel Burnier and Bocania.

A later article on the Gandarella area[a] reports the occurrence of manganese in two forms of deposits, (1) as veins of pyrolusite, and (2) as pebbles and blocks of pyrolusite in stream beds, which are derived from deposits composed of pyrolusite fragments embedded in red marl, resulting from the decomposition of manganese-bearing rocks. Streams flowing through these deposits separate the fragments from the marl. Itabirite is commonly found where ores occur, so it is probable that the Gandarella deposits were derived from the manganese bed described as in the Miguel Burnier district.

Analyses.—The following are analyses of manganese ore from the Ouro Preto district:

Analyses of ore from Ouro Preto branch line manganese deposits, Brazil.[b]

Mn	53.00
SiO_2	1.00
P	.03

Analyses of manganese ore from the Gandarella estate, Ouro Preto district, Brazil.[c]

	1.	2.	3.	4.	5.	6.
Volatile	1.00	1.00	1.50	1.75	1.95	2.00
Insoluble	1.14	.50	1.50	.45	1.74	1.65
MnO_2	92.31	87.27	78.94	78.93	89.76	90.79
P	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
S	Trace.	Trace.	None.	Trace.	None.	None.
MgO	Trace.	Trace.	None.	Trace.	None.	None.
CaO	.20	1.23	None.	1.41	1.50	.90
Iron oxide and alum	6.50	10.50	18.60	18.12	8.12	7.00
Mn	58.36	55.48	49.90	49.35	56.74	57.30

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[a] Mineral Resources U. S. for 1901, p. 140.

[b] Mineral Resources U. S. for 1905, p. 98.

[c] Mineral Resources U. S. for 1901, p. 142.

LAFAYETTE OR QUELUZ DISTRICT.

General statement.—The deposits of the Lafayette or Queluz district are of a different nature from those of either the Miguel Burnier or the Ouro Preto district. The country rock is granite, gneiss, and mica schist, with a complete absence of limestones, Jacutinga, and others of the Itacolumite series. The ore is largely psilomelane and occurs in disseminated or brecciated surface deposits in clay or in large lenticular masses, varying in extent from a few meters to 100 meters or more. It is derived from the oxidation of lenses of manganiferous rock, consisting principally of rhodochrosite and tephroite. The clays containing the ore are derived from the disintegration of the granite and schist which inclose the manganiferous rock lenses. In this district are included the mines of Barrosa, Morro da Mina, Piquery, and São Gonçalo.

Piquery mine.—In a recent paper[a] Derby states that the oxidized ore of the Piquery mine has been largely removed, thus exposing the unaltered rock from which they were derived. This consists of a "black, fine-grained, highly-jointed, and somewhat flaggy rock with the aspect of a limestone, which contains broad bands and patches of a more massive yellowish-gray rock with the aspect of a quartzite." The first rock, on treatment with cold dilute acid, effervesces with the abundant separation of gelatinous silica, leaving an insoluble residue of graphite and spessartite. The solution contains much manganese and small amounts of lime and magnesia. The quartzite-like rock also effervesces somewhat, upon treatment with acid, with the separation of gelatinous silica. It contains a larger amount of spessartite than the other rock and some asbestiform amphibole; locally it contains considerable rhodonite concentrated in streaks and patches.

Microscopic examination shows the limestone-like rock to be composed of rhodochrosite, with probably dolomite, tephroite, and spessartite, the last being present in varying small quantities. Locally rhodonite occurs, and pyrite, ilmenite, and pyrophanite are accessory minerals. The quartzite-like rock differs from the other in containing a larger amount of spessartite and rhodonite, some amphibole, and a smaller amount of rhodochrosite and tephroite. The surface ores are largely psilomelane.

The following analyses give the composition of different phases of the limestone-like rock:

Analyses of unaltered manganiferous rock from Piquery mine, Brazil.[b]

	1.	2.	3.
CO_2	22.62	4.59	....
SiO_2	11.80	27.67	38.47
MnO	47.52	57.48	27.90
Al_2O_3	7.50	1.41	21.07
Fe_2O_3		2.48	7.38
CaO	3.76	1.82	4.70
MgO	6.27	4.60	....

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[a] Derby, O. A., Am. Jour. Sci., March, 1908, p. 213.

[b] Derby, O. A., op. cit., p. 214.

São Gonçalo and Morro da Mina mines.—In the São Gonçalo and Morro da Mina mines the types of ores are very nearly the same. The unaltered material has a light-colored earthy aspect, platy structure, and spongy texture, due to numerous minute rounded cavities. The ore changes on weathering to the same type of oxidized ore (psilomelane) as that at Piquery.

Analyses.—The following are analyses of manganese ore from the Lafayette or Queluz district:

Average analyses of manganese ore from the Lafayette or Queluz deposits, Brazil.

	1.	2.	3.
Mn	47–50	49–51	50–52
SiO	3– 6	5– 7	1– 2
P	.08–.12	.08–.10	.12–.15
Moisture	....	3– 5	3– 5

1. Mineral Resources U. S. for 1905, p. 98.
2. Piquery mine. Mineral Resources U. S. for 1901, p. 142.
3. São Gonçalo mine. Same reference as 2.

AMAZON VALLEY.

Peculiar manganese deposits,[a] consisting largely of psilomelane, occur in the Amazon Valley in the district covered by the periodical floods. The ores occur embedded in sandstones in concretionary masses with botryoidal and stalactitic forms. In many parts the deposits contain an abundance of sand grains, so that they form a manganiferous sandstone. The ores are of the nature of bog deposits.

CHILE.[b]

DISTRIBUTION OF DEPOSITS.

Manganese ores are widely distributed in Chile, but the principal deposits are between 27° and 34° south latitude. They are all on the west slope of the Andes Mountains and are grouped into four districts, namely: Aculeo, in the Province of Santiago; Corral Quemada, in the Province of Coquimbo, and Huasco and Carrizal, in the Province of Atacama. Ores were discovered in the Aculeo district about 1880, and the first ore was exported in 1888. Mining operations soon ceased, however, because of lack of transportation facilities. About 1884 ore was discovered in the Corral Quemada district, and in 1886 the deposits of Carrizal were found.

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[a] Katzer, Ein eigentümliches Manganerz des Amazonasgebietes: Österr. Zeitschr. für Berg- und Hüttenwesen, vol. 46, 1898, pp. 41–46.

Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, pt. 1, p. 263.

[b] References on Chilean manganese-ore deposits:

Mineral Resources U. S. for 1886, p. 206.
Mineral Resources U. S. for 1888, p. 139.
Mineral Resources U. S. for 1891, p. 138.
Mineral Resources U. S. for 1892, p. 208.
Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 439.
Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, 1899, p. 142.
Mineral Resources U. S. for 1901, p. 144.

ACULEO DISTRICT.

The Aculeo district is situated about 32 miles south of Santiago and 6 miles from the Southern Railroad at Hospital station, to which the ore was carried in ox carts. The country is a rolling plain about 1,290 feet above sea level. The manganese ore was originally found outcropping on an elongated north and south hill about a quarter of a mile long and 350 feet above the plain. The lode has a dip of 30° S. The ores are hard and brittle, have a reddish tinge, and yield about 50 per cent manganese. Several other deposits have been discovered recently in this region.

CORRAL QUEMADA DISTRICT.

The Corral Quemada or Coquimbo district is situated on a plain about 30 miles south of Serena and 20 miles from the railroad station of Angostura, and is 4,722 feet above sea level. The mines are located within a circumference of 5 miles. The ore was carried to Angostura on pack mules and thence to the port of Coquimbo by rail.

The deposits occur on the plain as horizontal layers between earthy matter. The ores are soft and crumble easily and have a dark bluish color. They are valuable on account of containing a considerable percentage of lime (12 to 20 per cent). Ores of a poorer grade than those on the plain occur on a black mound called Negra Loma, about 2,300 feet long and 50 feet above the plain.

The following are analyses of ores from the Corral Quemada district:

Analyses of manganese ores from the Corral Quemada district, Chile.[a]

	Santo Tomas mine.	Guillermo mine.
Mn	51.65	50.08
Insoluble	8.40	9.63
SiO_2	5.95	4.73
CaO	8.90	4.90
H_2O	.15	.27

[a] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, 1899, p. 145.

HUASCO DISTRICT.

The Huasco district is on the north and south banks of Huasco River. It is sometimes included in the Carrizal district immediately to the north. On the south side of the river manganese ore of poor quality has been found in perpendicular lodes. It is of no commercial value. Northward from the river are other deposits, the principal ones being in a ridge about 18 or 20 miles distant, in association with large deposits of manganiferous iron ore. Beyond the ridge, in the plain about Salitre, there are scattered surface deposits of no value.

CARRIZAL DISTRICT.

The Carrizal district is among barren mountain ridges southeast of the seaport of Carrizal. From that port a railroad ascends the mountains by a circuitous route to the copper camp of Cerro Blanco. About 30 miles east of the seashore a branch line 20 miles long turns southward and connects with the manganese district at the foot of the Tenmile Mountains. A spur from the mountains forms a line of pyramids and mounds, the highest of which are the Coquimbana, the Porvenir, and the Cerro Negra. Manganese ore is found on the tops of these mounds in parallel perpendicular lodes running down to an unknown depth. The lodes average from 13 to 17 feet wide, the spaces between them consisting of reddish clay and sandstone. They are faulted at many points, but by careful measurements the continuations are found. The ores are hard and brittle and of a dark-bluish color.

The following are analyses of manganese ore from the Carrizal district:

Analyses of manganese ore from the Carrizal district, Chile.[a]

	Coquimbana.	Porvenir.	Monte Negra.
Mn	51.18	40.26	48.85
SiO_2	9.32	11.77	8.40
P	.079	.081	.090

[a] Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, 1899, p. 146.

MINOR DEPOSITS.

Recently other manganese deposits have been discovered in Chile in the same general region. Among them are the deposits in the Los Chorros district south of Huasco, and in other places in Atacama, those near San Felipe in Aconcagua, and minor deposits in the Provinces of Santiago and Coquimbo.

ANALYSES.

The following are analyses of cargoes of Chilean manganese ores:

Cargo analyses of Chilean manganese ores.[a]

	1.	2.	3.
MnO_2	69.23	55.06	66.03
MnO	11.92	23.05	10.39
Fe_2O_3	1.62	4.71	1.50
PbO	.09	.06	.05
CuO	.15	None.	.14
ZnO	.10	None.	None.
Al_2O_3	4.21	2.80	1.60
BaO	None.	None.	3.58
CaO	1.13	2.33	5.36
MgO	.24	.56	.13

[a] Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 442.

Cargo analyses of Chilean manganese ores—Continued.

	1.	2.	3.
K_2O	2.86	0.46	0.15
Na_2O	.08	.26	.11
SiO_2	4.17	7.30	4.75
CO_2	None.	.18	2.53
SO_3	.05	.13	1.57
P_2O_5	.12	.14	.05
As	....	.15	.04
H_2O+	3.90	3.00	1.96
	99.92	100.19	99.94
Mn	53.	52.66	49.79
S	.02	.05	.63
P	.05	.06	.02

EURASIA AND AFRICA.

SPAIN.[a]

Manganese occurs in Spain in the following associations and localities: (1) As carbonate and silicate in the Province of Huelva; (2) as oxide in the Provinces of Oviedo, Teruel, and Ciudad Real; and (3) in manganiferous iron ore in the Province of Murcia.

HUELVA DISTRICT.

Huelva is in southwestern Spain on the border of Portugal. Geologically the region consists of Paleozoic slates in which large tracts of eruptive rock are embedded. The ores are interbedded with Silurian (Culm) clay slate as lenses and beds associated with copper ore and quartzite or jasper. The lenses generally are found at the contact of jasper and clay slate and vary in length from 65 to 1,000 feet, and in thickness from a few feet to 150 feet or more. Several hundred of these lenses are known to exist. Pyrite is found in the same series in a similar manner.

The development of the mines was begun in 1860, the ores mined being oxides, largely psilomelane, which constituted the upper portions of the deposits. By 1880 most of the oxides had been removed and the mines were abandoned. About 1893 it was discovered that certain rocks in the abandoned workings had a black coating due to oxidation of the manganese compounds. Analysis showed these rocks to be manganese carbonate and silicate, and mining was recommenced.

The oxide ores, as a rule, do not extend much more than 65 feet below the surface, although occasionally they are found below 100 feet, and in one mine at 330 feet. The oxides are mostly pyrolusite and psilomelane. They are now nearly exhausted, and the ore mined lately has been very largely carbonate and silicate, which occur in great quantities.

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[a] References on the manganese-ore deposits of Spain:

Mineral Resources U. S. for 1887, p. 159.

Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 453.

Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 318.

Wetzig, Bruno, Beiträge zur Kenntniss der huelvaner Kieslagerstätten (Review): Trans. Inst. Min. Eng., vol. 33, pt. 6, 1908, p. 707.

Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, pt. 1, p. 251.

The following are analyses of carbonate ore from the Province of Huelva:[a]

Analysis of crude carbonate ore, Ysabel, Spain.

Loss by roasting (Co_2, etc.)	28.26
MnO	52.99
Fe_2O_3	2.14
SiO_2	10.20
Al_2O_3 and P_2O_5	.86
CaO	4.69
MgO	.84
	99.98
Mn	40.80
Fe	1.50

Cargo analyses of crude carbonate ore, Huelva, Spain.

	1.	2.	3.
Mn	42.6	41.3	41.2
SiO_2	10.46	10.5	9
P	.07	.10	.08

The following are analyses of Huelva oxide ores:[b]

Analyses of Resucitada (1) and Santa Aqueda (2) manganese ore, Huelva, Spain.

	1.	2.
MnO	4.16	....
Mn_3O_4	....	70.92
MnO_2	56.87	....
H_2O+	6.80	....
CO_2	9.96	1.50
Fe_2O_3	6.57	3.52
SiO_2	9.10	0.25
Al_2O_3	1.52	2.30
CaO	3.20	1.17
MgO	.84	Trace.
S	.17	....
P	.09	.036
As	.028	.028
Cu	Trace.	Trace.
Mn	39.2	51.10
Fe	4.6	....

COVADONGA DISTRICT.

The Covadonga district is situated in the Province of Oviedo, in northern Spain. It is in a level valley in the Cantabrian mountain chain at the foot of Picos de Europa. Behind it limestone ranges rise abruptly in precipitous peaks, with interlying valleys, culminating in Peña Santa, 8,266 feet, and Picos de Cornion, 8,462 feet above sea level. A line between these peaks passes over the manganese deposits. Rivadesella, about 25 miles north, is the shipping port.

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[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, pp. 319, 320.

[b] Idem, p. 320.

The manganese ore was discovered about thirty-five years ago in huge isolated blocks, entrapped between the serrated outcrops of the limestone ranges, where they had rested in their downward course from higher elevations. These blocks were broken up and carried down to Covadonga, from whence they were transported on donkeys to Rivadesella. Later, a government road was installed between these towns and the ore was hauled on carts. When the isolated bowlders were exhausted, open cuts were started at the foot of the limestone outcrops, and ore was discovered as fragments in glacial clays. Borings have shown the manganese to be scattered over the whole of the flat area between the limestone ranges, and not confined to narrow limits.

The ores are oxides found in manganiferous and ferruginous clay. The lower portion of the deposit consists of manganiferous clay, which grades upward into a clay strongly stained by hematite, which has given the name "Redcap" to the formation. Both types of clay contain lumps of manganese and iron ore, the former being more abundant in the lower part. Above the ore deposit is a few feet of blue clay with limestone nodules, and above this are bowlder clays containing angular and rounded fragments of limestone, sandstone, and shale, and in some places small lumps of cinnabar.

High up in the mountains above the deposits is a clean rock fissure, 6 feet wide, that has held manganese ore similar to that found in the deposits below, and also contained nodules of cinnabar. It was worked many years ago by a Belgian company and the ore has been removed. This fissure is taken to be the remains of what was once an extensive bed, the disintegration of which yielded the ores of the lower deposits.

The carrying of the ores down the mountains and their deposition throughout the level area where they now occur are supposed to have been performed by glaciers.

The following are analyses of manganese ore from Covadonga:

Analyses of manganese ore from Covadonga, Spain.[a]

	Asturiana mine.	Asturiana and Magenta mines.
Mn	58.26	58.35
Fe	1.42	1.10
SiO_2	1.66	.90
P	.016	.01
Ca	....	Trace.
H_2O	1.33	....

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[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 322.

MINOR DEPOSITS.

In the northwestern part of the Province of Ciudad Real manganese ores occur as a bed 4 feet thick overlain by white Miocene clays, which also carry 15 to 20 per cent ore. The ore contains 40 to 60 per cent manganese and 0.25 per cent phosphorus. The manganese deposits of the Province of Teruel consist of oxides, but their associations are not known.

In the districts of Cartagena and Aguilas, in the Province of Murcia, large deposits of manganiferous iron ore are worked. In the district of Cartagena the manganiferous ores occur in an east and west range of mountains. In many of the mines lead and silver ores are found under the manganiferous iron ores. The manganese content varies from 10 to 20 per cent and the iron content from 20 to 35 per cent. The ore also contains considerable silica.

The following are analyses of manganiferous iron ore from the Province of Murcia:

Analyses of manganiferous iron ores from southern Spain.[a]

	Cartagena.	Aguilas.
Fe_2O_3	35.84	69.92
Mn oxide	30.89	7.57
CO_2, combined H_2O, etc	16.33	12.90
CaO		1.45
Al_2O_3	.31	.61
SiO_2	5.14	8.00
P_2O_5	.04	.02
SO_3	.31	.14
ZnO	.84	
MgO	.45	.23
Fe	25.09	48.67
Mn	22.26	5.74

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 323.

The iron ore from the Province of Almeria contains 2 to 6 per cent manganese, and that from the district of Parazuelos contains about 3 per cent manganese.

PORTUGAL.[a]

Manganese ore occurs in Portugal in the district of Beja, Province of Alemtejo. In this district there are eight or ten large mines, of which some produce manganese carbonate, yielding 34 to 50 per cent manganese, and others produce oxides.

The following are analyses of Portuguese manganese ores:

Analysis of manganese oxides from Alonzo Gomez mines, Portugal.[a]

	1.	2.	3.	4.	5.	6.
MnO_2	72.56	76.75	72.21	80.86	71.88	
SiO_2	4.71	6.58	4.75	2.78	1.62	8.50
Fe	2.14	2.34	2.03	2.27	3.59	2.25
Mn	55.20	54.88	54.65	59.73	51.03	48.25
P	.03	.04		.04		.05

[a] Mineral Resources U. S. for 1901, p. 149.

FRANCE.[a]

The principal manganese mines of France are the Romaneche mines, in the western and central parts of the department of Saône-et-Loire, in east-central France, and the mines of Las Cabesses, Cazalas, and Brachy, in the department of Ariège, near the Spanish boundary. The Saône-et-Loire mines ship binoxide and the mines of Las Cabesses ship calcined and assorted carbonates.

Smaller deposits of ore occur at Chaillac, in the department of Indre, in central France; at Ferronnière and Villerambert, in the department of Aude, in southeastern France; and in the departments of Allier, Hautes Pyrénées, and Lozère.

The deposits at Romaneche[b] occur along a fault contact where sediments of the Lias, Keuper, and Tertiary are brought in contact with granite. Two northeast-southwest-striking vertical veins occur in the granite and unite to form the "grand filon" (big vein) along the fault contact, which has a dip of 70°. The veins in the granite vary in thickness up to 20 feet and have no definite walls. The "grand filon" varies in thickness from 16 to 26 feet and has a definite foot wall of granite.

The principal ore is psilomelane, accompanied by quartz, barite, fluorspar, and a small amount of arsenosiderite. With depth a considerable quantity of hematite appears.

The deposits at Las Cabesses[c] are in Ariège, 9 miles east of St. Girons. They consist of manganese carbonate occurring as lenses in a limestone formation of Devonian or Mississippian age called the Griotte. The formation is 1,000 feet thick, consists of white, red, green, and black limestones, and is overlain by phosphatic beds. Between 1881 and 1890 the deposits were mined along the outcrop, where they consisted of oxides. At a depth of about 65 feet a pure carbonate was reached and this is mined at present. The beds are very much folded and faulted.

The ore is gray, brown, and red and has a compact texture. The following is an average analysis:

Average analysis of manganese carbonate from Las Cabesses, France.

Mn	40–42
Fe	1.5–2
CaO	6
P	0.04–0.05

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[a] References on French manganese ores:
Stelzner, A. W. and Bergeat, A., Die Erzlagerstätten, pp. 249–251, 1047, and 576.
Mineral Resources U. S. for 1888, p. 141.
Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 445.
Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, p. 210.
Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, 1898, p. 111.
Mineral Resources U. S. for 1901, p. 145.

[b] Stelzner and Bergeat, op. cit., p. 576.

[c] Idem, p. 1047.

A small deposit of gray manganese carbonate with a capping of oxides is reported from Rivernert, near St. Girons.

At Gouttes-Pommiers,[a] in Allier, pyrolusite occurs in yellow and red ferruginous quartz in Cambrian schist and marble, and at Luzy, in Nièvre, it occurs in granite.

At several localities in the department of Hautes Pyrénées[b] finely laminated beds of rhodonite and friedelite in quartz occur interlayered with Devonian clay slates containing trilobites. In a few places they are superficially altered to oxide and carbonate.

The following are analyses of French manganese ores:

Cargo analysis of French manganese ore.[c]

MnO_2	21.72	As	0.06
MnO	29.06	Zn	Trace.
Fe_2O_3	15.86	Cu	Trace.
Al_2O_3	9.07	CO_2	.80
MgO	4.81	H_2O+	.41
CaO	5.90		
SiO_2	9.55		98.92
BaO	1.34	Mn	36.24
P	.05	Fe	11.10
S	.29		

Analysis of Saône-et-Loire manganese ore.

Mn	40.00
Fe	1.50
BaO	13.00
SiO_2	6.20

BELGIUM.[d]

Belgium does not produce manganese ores proper, but a considerable amount of manganiferous iron ores. The center of production for these is the Province of Liege. The manganese ore occurs at Chevron, in this province, as rhodochrosite associated with iron ores in upper Silurian rocks. They are also found elsewhere in Belgium associated with hematite.

The following are analyses of manganiferous iron ore from Chevron:

Analyses of manganiferous iron ore from Chevron, Belgium.[e]

	1.	2.
Mn oxides	28.42	31.75
Fe_2O_3	29.62	24.15
Al_2O_3	3.87	4.06
CaO	3.90	2.83
MgO	1.15	.88
SiO_2	23.22	22.01
P_2O_5	.55	.46
SO_3	Trace.	.01
CO_2	10.63	14.51
	101.36	100.66
Mn	20.48	22.87
Fe	20.73	16.90
P	.24	.20

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[a] Stelzner and Bergeat, op. cit., p. 576.

[b] Idem, p. 249.

[c] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, 1898, p. 111.

[d] References to manganese ores of Belgium: Mineral Resources U. S. for 1893, p. 146.

[e] Mineral Resources U. S. for 1887, p. 158.

GERMANY.[a]

The chief occurrence of manganese in Germany is along the Rhine in the districts of Wiesbaden and Koblentz, in Hesse-Nassau. Smaller deposits are found in the Harz Mountains, in Saxony, in the Bonn district, and in Coburg-Gotha, in Thuringia. Manganese ores occur with spathose iron ore at Siegerland and with the brown ores of Upper Silesia, Osnabrück, and other places. A large proportion of the manganiferous iron ores of Germany are produced in Prussia.

Manganese ores associated with iron ores occur disseminated and in large masses in clays overlying the *Stringocephalus* limestone (Middle Devonian) in Hesse-Nassau,[b] the principal deposits being in the southern part of Hesse. The upper surface of the limestone is very uneven, consisting of numerous domes and ridges separated by intervening crevices and troughs filled with clay. The principal localities in this district are the area around Giessen; the area between Homburg, in Hesse-Nassau, and Friedberg, in Upper Hesse; the area around Limburg, in Hesse-Nassau; and the district between Stromberg and Bingerbrück, on the opposite side of the Rhine. Near Giessen extensive mining operations are being carried on at Lindener Mark. The ore occurs in troughs of clay on the uneven surface of the *Stringocephalus* limestone. This rock is dolomitized on the surface to depths ranging up to a meter and in many places is stained with iron and manganese oxides. Near the surface of the dolomite is an earthy manganiferous iron ore and above this a variegated clay containing beds and nodules of similar ore scattered irregularly. These clays grade upward into gray and blue plastic clays (Tertiary) which in turn are covered by sand and gravel. The ores consist of psilomelane, wad, hematite, and limonite. Many geodes consisting of concentric layers of these minerals occur in the clay.

In the vicinity of Homburg mining is carried on at several localities, but especially at Oberrosbach. Here a deposit of manganese ore several meters thick occurs in sand overlying the surface of the *Stringocephalus* limestone. The ores contain 25 to 26 per cent manganese and about the same quantity of iron.

At Niedertiefenbach,[c] Heckholzhausen, and other localities near Limburg iron and manganese ores occur at depths from 30 to 160 feet under loess, gravel, and much-decomposed diabase. The foot wall here also is formed by the dolomitized *Stringocephalus* limestone. Above the limestone there are successive layers of clay which contain iron and manganese ores, the former more abundant at the top and the latter at the base of each layer. The ores are thought to have been derived from the now decomposed diabase. The deposit at Heckholzhausen is covered with 45 feet of Tertiary clays and basaltic gravel and shows a thickness of 15 to 21 feet. The ore is amorphous manganic oxide, averaging 65 to 70 per cent manganese oxide, and contains large pockets of crystalline manganite and pyrolusite averaging 85 to 90 per cent manganese oxide.

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[a] References to German manganese ores:
Mineral Resources U. S. for 1887, p. 161.
Mineral Resources U. S. for 1893, p. 147.
Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 448.
Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, pp. 250, 573-575, 1015-1020, and 1042.

[b] Stelzner and Bergeat, pp. 1015-1020.

[c] Stelzner and Bergeat, op. cit., pp. 1016-1017.

Near Bingerbrück an earthy manganese deposit occurs partly between a clay shale layer and the *Stringocephalus* limestone and partly above the shale layer. At the Amalienhöhe mine near Waldalgesheim in the same region there is an extensive deposit of manganiferous iron ore carrying from 5 to 22 per cent manganese and up to 40 per cent iron. The ore occurs in masses several meters in diameter in decomposed, variegated, argillaceous schist overlain by a bed of Tertiary sandstone, gravel, and clay several meters thick. Mining has been carried to a depth of 377 feet. The clay carries an average of 2.4 to 2.7 tons of ore per cubic meter.

Earthy manganese ore deposits occur in Permian dolomite or on the underlying Rothliegendes at Waldmichelbach and other less important localities in Odenwald,[a] which comprises parts of Hesse, Baden, and Bavaria. The dolomite overlies the Permian Rothliegendes sandstone and is overlain by 3 to 100 feet of red clay and schistose plastic clay belonging to the lower Bundsandstein of the Triassic. The surface of the dolomite is irregular and the manganese lies on it or has replaced parts of the dolomite itself. Locally the dolomite has been decomposed altogether and the ore lies on the Rothliegendes. The ores contain 10 to 22 per cent manganese and about the same quantity of iron. In addition many of them contain quartz, barite, copper, zinc, arsenic, cobalt, and nickel. Because of the presence of the metalliferous minerals it has been supposed that the ores originated from ascending thermal waters. It is to be noted that these deposits are very similar to those of Batesville, Ark.

At Elbingerode,[b] in the Harz Mountains, manganese silicates of various colors occur in a zone 26 feet wide in quartz schists of the Culm. They are associated with quartz and are superficially altered to manganese oxides and carbonate. The unaltered material consists of quartz and pale-red manganese pyroxenes, largely rhodonite. The oxidized material has all been mined and consisted largely of pyrolusite and psilomelane with impurities in the form of manganese silicates and fragments of schists.

In Biedendorf and Hadamar, in Hesse-Nassau, are found deposits of manganese similar to those at Elbingerode and in schists of the same age.

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[a] Stelzner and Bergeat, op. cit., p. 1042.

[b] Idem, p. 250.

Veins of manganese ore containing chiefly manganite, subordinately pyrolusite, braunite, hausmannite, psilomelane, wad, and varvacite, occur at the Ilfeld,[a] in the Harz Mountains. The associated gangue minerals are barite, calcite, dolomite, and manganiferous calcite. The veins are found in porphyry and range in thickness from a few inches to 2 feet and in depth from 15 to 35 feet, though occasionally reaching a depth of 90 feet.

At Elgersburg,[a] in the Thuringerwald, pyrolusite and psilomelane, associated with hausmannite, braunite, and wad, occur in veins which in some places reach a width of 9 to 13½ feet, and have been traced for more than three-fifths of a mile. The gangue minerals are largely calcite and barite; the inclosing rock is porphyry. Similar veins occur in melaphyre and porphyry at Ilmenau and Friedrichroda, in the same vicinity.

Near Schwarzenberg,[b] in southeastern Saxony, manganese oxides occur in association with iron ores. On Graul River near this locality there is a deposit of earthy manganese ore which contains up to 7 per cent bismuth and also some earthy cobalt.

SWEDEN.[c]

Manganese ores of three types occur in Sweden—(1) pyrolusite with manganite, (2) hausmannite with braunite, and (3) carbonate and silicate of manganese accompanying iron ores.

Pyrolusite with manganite.—Ores of the first type occur at Bolet and other places in Vestergotland, at Spexerejd, Höhult, Jacobsberg, and Ludwigsberg, in Smaland; at Skidberg and Nalberg, in the parish of Leksand, Dalarne, and at Spethult, Dalsland.

At Bolet the pyrolusite is found in fissures in a gneiss or gneiss-granitic rock. These fissures, which vary in breadth from a fraction of an inch to 5 feet, are filled with breccia, containing chlorite, mica, barytes, calcite, and in certain places pyrolusite and manganite, with some braunite and wad as infiltrating cement. The fissures range up to 245 feet in length. The inclosing gneiss granite also contains small grains of pyrolusite.

In the Smaland district ore occurs similarly to that at Bolet. The ore appears in fissures in a schistic granite, which are filled with breccia, held together by limestone and manganese ore, the latter consisting of pyrolusite, manganite, and wad.

In Dalarne and Dalsland ore is found in fissures which are so small as to be of no commercial importance.

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[a] Stelzner and Bergeat, op. cit., p. 575.

[b] Idem, pp. 573-574.

[c] References to Swedish manganese ores:
Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, pp. 241-244.
Mineral Resources U. S. for 1893, p. 143.
Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 449.
Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, p. 217.

Hausmannite with braunite.—Ores of the second type occur at Pajsberg, Långban, Jacobsberg, and Nordmark (in Wermland) and at Sjogrufvan in Orebro. The ore consists of hausmannite and braunite, and contains jacobsite and several rare silicates of manganese. The deposits are found in lenses of dolomite or limestone inclosed in granulite, and are associated with iron-ore deposits consisting of hematite and magnetite. The rocks are classified as upper Archean.

At Pajsberg [a] the manganese-ore deposits are associated with iron-ore deposits, and both are inclosed in dolomite. Hausmannite occurs disseminated through the dolomite and in granular concretions and is associated with a large number of silicates and carbonates, some of them very rare.

The deposits of Långban [a] occur in the southern part of an area of dolomite striking north and south, about 2½ miles long and 1¼ miles wide, inclosed in granulite. The ore deposits themselves have an east and west strike. They are associated with a large amount of gangue material known as "skarn." At least six deposits are known at this locality. Single deposits vary in thickness, and some of them divide or become disseminated through the dolomite or "skarn." The ore-bearing zone in places has an average width of 1,000 feet. The following section shows in general the layering of the ore-bearing bed:

Section of the ore bed at Långban, Sweden.[b]

Dolomite.
Grünskarn (gangue minerals) with disseminated magnetite and in many places hematite.
Magnetic iron ore with black garnet.
Hematite with ferruginous quartz.
Hausmannite with dolomite.
Braunite.
Manganese silicates (schefferite, tephroite, richterite, rhodonite, etc.).
Dolomite.

The manganese ores carry a small quantity of iron, generally less than 1 per cent. The associated iron ores carry about the same percentage of manganese and consist of 70 to 80 per cent hematite, the rest being magnetite. This is significant because of the fact that the Swedish iron ores of this type that are not associated with manganese ores consist almost entirely of magnetite.

At Jacobsberg and Nordmark [c] hausmanite and braunite occur in limestone instead of dolomite. The ore-bearing bed has a maximum thickness of 13 feet. The manganese ores are not very important at these localities, the principal ores being magnetic iron ores, with which the former are associated.

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[a] Stelzner and Bergeat, op. cit., p. 242.
[b] Idem, p. 243.
[c] Idem, p. 244.

The manganese deposits at Sjogrufvan[a] occur in an area of dolomite 2½ to 3 miles long and several hundred yards wide, surrounded by granulite. The deposit is about 25 or 30 feet wide and 330 feet long, and consists of very pure masses of braunite and hausmanite 12 or 16 feet in diameter overlain by an iron-ore deposit consisting of hematite and magnetite.

Carbonates and silicates with iron ores.—The ores of the third type are iron ores, mainly magnetite, but with some hematite, containing manganese. The manganese minerals consist principally of manganese carbonate and silicate, but oxides also are found in those ores which are more highly manganiferous. The ores occur in strata in limestone and "halleflinta." The average manganese content of the ores is not more than 6 per cent, but percentages as high as 25 occur in many of the fields.

The principal localities at which these ores occur are in Dannemora, Klackberg, and Kohnigsberg, Burangsberg, Langnik, Viker, Hillang, and Svartberg. Other localities are Gladkärn, Robergsfältet in Norberg, Skimarang, Knipgrufvan, and Penninggrufvan.

GREAT BRITAIN.[b]

No pure manganese ores are mined in Great Britain, but small amounts of manganiferous iron ore are produced. The localities where most of the ore has been mined are Barmouth and Harleck, in Merionethshire, North Wales; Carnarvonshire, North Wales; Tavistock in Devonshire and Launceston in Cornwall, southwest England; and in Derbyshire and adjacent territory in the Midlands of England. The ore of North Wales consists mainly of carbonate with some silicate and oxide in Cambrian rocks; that of England is psilomelane and pyrolusite in lower Silurian strata.

NORTH WALES.

The Cambrian rocks of Merionethshire are comprised in an irregular oval mountain tract, the longer axis of which is 17 miles and the shorter axis 10 miles. They consist principally of coarse quartzite and greenish-gray grit, in some parts of which the quartz grains are interspersed with grains of feldspar. The ore lies in beds from a few inches to 4 feet thick, the average being 18 inches to 2 feet. The undecomposed portion of the bed contains manganese carbonate with a small proportion of silicate, but at the outcrop it is changed into a hydrated black oxide. The carbonate containing from 20 to 35 per cent manganese is the principal ore mined. There are three manganese lodes, the principal one running in an unbroken line for about 2 miles almost north and south. Two and one-half miles north of this and a little to the west is the second lode, which is about a mile long; and one-half mile farther north is the third lode, of about the same length. These beds were first worked for the superficial black oxide, and when this had been removed, about 1840, the mines were closed. In 1855 it was found that the oxide was simply the outcrop of impure beds of manganese carbonate and mining was resumed. The principal manganese lode is 8 to 18 inches thick, and in the Harleck mine consists of grit of medium grain, overlain by a thin band of quartzite. The roof consists of about 2 feet of hard schistose rock called "blue stone." The ore is in uniform layers, which are gray, white, yellow, green, and chocolate brown.

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[a] Stelzner and Bergeat, op. cit., p. 241.

[b] References on the manganese ores of Great Britain:
Mineral Resources U. S. for 1886, p. 199.
Mineral Resources U. S. for 1887, p. 154.
Mineral Resources U. S. for 1891, p. 143.
Mineral Resources U. S. for 1892, p. 219.

In some places the bed is considerably faulted and folded, so that mining is very difficult. Where the bed is thinnest the ore is richest. The ore is made up of about 30 per cent carbonate of manganese, 4 per cent silicate of manganese, 40 per cent oxides of manganese, iron oxides, carbonate and sulphide, magnesium carbonate, free silicate, etc., and 26 per cent clay.

Analyses of Merionethshire manganese ores follow:

Analyses of ore from Merionethshire, Wales.[a]

	1.	2.
Moisture	....	2.499
MnO_2	8.07	7.87
MnO	26.72	26.05
Fe_2O_3	5.71	5.57
Al_2O_3	10.99	10.72
CaO	4.31	4.20
MgO	.62	.60
SiO_2	26.67	26.00
K_2O and Na_2O	.25	.24
P_2O_5	.074	.072
SO_3	.17	.16
Loss on ignition (12.83 CO_2)	15.70	15.31
	99.284	99.291
Mn	25.8	25.05
Fe	4.0	3.90
P	.043	.042

[a] Mineral Resources U. S. for 1887, p. 158.

In the hills northeast of Arenig, in Merionethshire, consisting of upper Trappean ash with a mass of feldspathic porphyry, there are found various veinlike fissures of manganese and iron. These veins vary in width up to 3 feet, and are commonly separated from one another by several feet of soft rock. They are filled with impure earthy and brown oxide of iron, pyrolusite, and psilomelane.

MINOR DEPOSITS.

The manganese deposits of Devonshire and Cornwall were worked chiefly from surface openings, and the available ore has been removed. The deposits are known to extend downward, but the ore is of a poor grade and is mined but scantily.

The deposits of Derbyshire and adjacent parts of the Midlands are layers a few inches thick or, more generally, dark-brown or black masses of a crumbly, earthy appearance, not unlike that of hard balls of soot. The ore is soft and soils the fingers. The ore bodies occur in beds 6 inches to 2 feet thick, resting on blocks of limestone, and appear to be sedimentary deposits, presumably bog ore.

The following is an analysis of Derbyshire manganese ore:

Analysis of manganese ore (wad) from Derbyshire.[a]

	Parts.
Insoluble earth (micaceous)	2
Iron	9½
Manganese	9½
Lead	1
	22

AUSTRIA-HUNGARY.[b]

Manganese ore is found in different parts of Austria-Hungary, namely, in Bukowina, Carniola, Moravia, Bosnia, Herzegovina, Transylvania, and Bohemia.

Bukowina.—In southern Bukowina,[c] near the village of Jakobeni, is the manganese deposit of Arschitza. It is spread over an area 165 feet wide and 400 to 650 feet long and consists of a bed with a foot wall of quartzose hornblende-mica schist and a hanging wall of weathered brownish-yellow hornblende schist. The bed shows distinct layers and is composed of an upper workable portion consisting of manganese oxides, limonite, and quartz, and a lower barren grayish or bluish-black quartz schist 20 to 33 feet thick. The deposit originally consisted of manganese silicates with disseminated carbonate interbedded with mica-hornblende schist. Beds of this material are still exposed locally. The deposit reached its present condition through oxidation. The manganese ores are pyrolusite with cavities containing wad and botryoidal psilomelane.

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[a] Mineral Resources U. S. for 1887, p. 156.

[b] References on the manganese ores of Austria-Hungary:
Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, pp. 248-256, 575, and 635.
Mineral Resources U. S. for 1888, p. 142.
Mineral Resources U. S. for 1903, p. 151.

[c] Stelzner and Bergeat, op. cit., p. 248.

The following analyses show the composition of the ore:

Analyses of manganiferous iron ore from Bukowina.

	1.	2.
SiO_2	27.5	35.5
Fe_2O_3	25.6	25.0
CaO	0.5	....
MnO_2	32.4	28.4
Mn_3O_4	6.9	4.7
H_2O	7.1	6.4

Carniola.—In Carniola[a] manganese ores are found in the upper valley of Save River at Vigunsica near Radmannsdorf. The ore consists of impure oxides occurring as a bed 3 to 13 feet thick and about 1¾ miles long, in Triassic slates. It has hanging and foot walls of slate overlain by a brecciated limestone bed. Some of the ores contain as much as 45 per cent manganese.

Moravia.—Manganese carbonate occurs as concretions in Oligocene clays near Austerlitz[b] in central Moravia. Some of the masses are of the size of a man's head and are crusted with pyrolusite several centimeters thick. The interior mass contains manganese carbonate up to 40 per cent.

Bosnia.—The ore in Bosnia[c] is on a plateau 3,000 feet above the sea at Cevljanovic 16 miles north of Sarajevo, in a series of variegated Triassic sandstones, which overlie a limestone of the lowest Triassic. The ore is associated with beds of variegated jasper in the sandstone and may be traced in a north and south belt about 2,300 feet long and 325 feet wide. The deposits are 5 to 10 feet thick and are separated from one another by sandstone layers from a few inches to several feet thick.

The ore is mainly hard steel-blue psilomelane with a conchoidal fracture, containing from 50 to 54 per cent of manganese. With it is associated limonite. There is also a black porous ore resembling wad, which occurs in large quantities, but is of too low grade to be workable. Silicate of manganese occurs locally. About 7,000 or 8,000 tons of ore are produced annually.

The following are average analyses of the ore:

Analyses of manganese ore from Cevljanovic, Bosnia.[d]

	1.	2.
Mn	46.01	50.42
SiO	12.38	11.48
Fe	5.30	5.53
Al_2O_3	2.76	.90
P	.07	.07
S	.94	....

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[a] Stelzner and Bergeat, op. cit., p. 252.

[b] Idem, p. 256.

[c] Mineral Resources U. S. for 1888, p. 142; also Stelzner and Bergeat, op. cit., p. 252.

[d] Stelzner and Bergeat, op. cit., p. 253.

Ores similar to those in Bosnia occur in small quantities at Ivanjska and other localities in Servia, east of Bosnia.

Transylvania.—Alabandite, along with many other sulphides, occurs as a gangue in gold quartz veins at Nagyag,[a] in the Erz Gebirge, in western Transylvania.

Bohemia.—Near Pribram,[b] in Bohemia, decomposed and weathered veins of manganese ore are associated with diabase. The ores consist of pyrolusite and wad with small quantities of hematite, göthite, and limonite. The gangue material is largely quartz with subordinate amounts of calcite.

SWITZERLAND.

At Roffna,[c] in Oberhalbstein, in the Swiss Canton of Graubünden, manganese ore occurs as beds in slates of Jurassic or Tertiary age. The ores are pyrolusite, polianite, and psilomelane penetrated by quartz veins and grading into quartz slate and red jasper.

ITALY.[d]

The chief manganese deposits in Italy are on Monte Argentario, at Carrara, at Rapolano, and on the island of Elba, in Tuscany; at Turin and Pralorgnan, in Piedmont; and at Gambatesa, in eastern Liguria. There are small mines at Iglesias, on San Pietro Island, off the west coast of Sardinia. Manganiferous iron ore occurs in Tuscany in the Apennines, near Florence. Manganese ore averaging 73 to 75 per cent oxide and manganiferous iron ore have been reported from Salerno, in Campania, on the coast south of Naples.

At the San Marcel (Aostatal) deposit, near Pralorgnan,[e] in northwestern Piedmont, the ore consists largely of pyrolusite formed by the alteration of rhodonite. The deposits occupy a bed about 26 feet wide and over 325 feet long in gneiss, and in it the pyrolusite occurs in masses 4 or 5 yards in diameter. With the pyrolusite are associated braunite, hausmannite, quartz, piedmontite, spessartite, and other manganese silicates.

The deposits at Gambatesa[f] consist of manganite and pyrolusite in red quartz slates. The mines are at present idle, but have been among the most important in Italy, some of the ore containing as much as 50 per cent manganese.

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[a] Stelzner and Bergeat, op. cit., p. 635.

[b] Idem, p. 575.

[c] Idem, p. 253.

[d] References on the manganese-ore deposits of Italy:
Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, pp. 247, 254, 260, 1048.
Mineral Resources U. S. for 1886, p. 202.
Mineral Resources U. S. for 1887, p. 161.
Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 446.
Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, p. 214.
Tonietti, G., Manganese ores in Elba: Min. Jour., vol. 84, p. 459; also Jour. Iron and Steel Inst., 1908, p. 496 (review).

[e] Stelzner and Bergeat, op. cit., p. 247.

[f] Idem, p. 254.

The ores at Monte Argentario[a] are near Santo Stefano, on the coast of Tuscany. They occur in irregular deposits in Rhætic limestone along the contact of Permian quartzite and argillaceous slate. The ores are a mixture of ocherous limonite and manganese, in some places one and in some the other being predominant. Together they compose about 50 per cent of the ore. Most of the ore is in the limestone, where at present a deposit 820 feet long and 100 feet thick is being worked.

The manganese ores on the island of Elba are said to occur in extensive deposits embedded in limestone or siliceous rock.[b]

On San Pietro Island[c] the ore occurs in two seams, on an average 1 foot thick. The beds are separated by a thin layer of black clay and are overlain by a 4½-foot bed of red and yellow jasper. The ore is brown to black and together with the jasper is inclosed in a bed of soft white and red clay with trachyte fragments. The entire series is inclosed between beds of trachyte. The best ore contains 31 to 35 per cent manganese and 7 to 13 per cent iron.

GREECE.[d]

Manganiferous iron ore containing 18 to 19 per cent manganese and 34 to 35 per cent iron occurs at Laurium, in Greece. Manganese ore is found in small amounts in several localities, among which are Cape Vani, on the island of Melos, and Fourkovuni Point, also in the Cyclades. The ores at Cape Vani are in Pliocene clays in deposits 1½ to 5 feet thick. The ore-bearing bed has a hanging wall of trachyte. The ore beds at Fourkovuni Point occur in parallel layers in a hill rising abruptly from the shore to a height of 400 feet. The layers are said to be from 2 to 6 feet thick and to consist of intermixed ore and clay.

A manganiferous iron ore containing 7 to 15 per cent manganese and 33 to 50 per cent iron, said to be Grecian, has been shipped from Mazarron, in Spain; but the locality of the mines is not known. The following analyses give the composition of this ore:

Analyses of manganiferous iron ore from Greece.[e]

	1.	2.
SiO_2	3.60	5.02
Fe	50.00	33.59
Mn	7.64	15.33
P	.022	.048

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[a] Stelzner and Bergeat, op. cit., p. 1048.

[b] Tonietti, G., loc. cit.

[c] Stelzner and Bergeat, op. cit., p. 260.

[d] References on the manganese ores of Greece:
Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, p. 260.
Mineral Resources U. S. for 1886, p. 203.
Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 447.
Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, 1898, p. 121.

[e] Mineral Resources U. S. for 1886, p. 203.

TURKEY.[a]

Manganese ores occur both in European and in Asiatic Turkey. In the former they are found in southern Macedonia, the shipping port being Stratoni, on the Ægean Sea. In the latter, they are reported from Aptal in Trebizond, in northern Asia Minor, near the Black Sea, and also from Flatza, in the same region.

On the island of Cyprus,[b] off the south coast of Asia Minor, manganese ores occur at Strullos, near Larnaka. The ore occurs in Miocene marl in the vicinity of areas of quartz andesite and tuff, and consists of nodules of pyrolusite and psilomelane grading into earthy iron and manganese ores.

The following analyses show the composition of the ore:

Analyses of manganiferous iron ore from Cyprus.

	1.	2.
MnO_2	24.85	24.42
Fe_2O_3	40.03	41.27
SiO_2	12.28	19.56
Al_2O_3	5.20	6.61
$CaCO_3$	8.41	Trace.
$MgCO_3$	1.70	1.02
H_2O and organic	7.53	7.22

RUSSIA.[c]

Russia has been for many years the leading producer of manganese in the world. By far the largest part of the ore has come from the Sharopan district in the Province of Kutais, Transcaucasia, on the Asiatic slope of the Caucasus Mountains. Smaller amounts of ore have been produced in the Nikopol district in the Province of Ekaterinoslav in south Russia, and in the provinces of Perm and Orenburg in the Ural Mountains.

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[a] References on the manganese ores of Turkey:
Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, p. 260.
Mineral Resources U. S. for 1888, p. 142.
Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 325.

[b] Stelzner and Bergeat, op. cit., p. 260.

[c] References on the manganese ores of Russia:
Drake, Frank, The manganese-ore industry of the Caucasus: Trans. Am. Inst. Min. Eng., vol. 28, 1898, p. 191.
Yakovlev, N., Gisements de manganese du district minier de Nizhine Taghilsk: Review in Trans. Inst. Min. Eng., vol. 33, pt. 6, p. 695.
Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, pp. 258–260.
Mineral Resources U. S. for 1886, p. 204.
Mineral Resources U. S. for 1893, p. 138.
Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 443.
Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, 1898, p. 112.
Mineral Resources U. S. for 1905, p. 104.

SHAROPAN DISTRICT.

The Sharopan district is near the town of Chiaturi, about 26 miles northeast of Kvrilli station, or Sharopan, on the Transcaucasian Railway, which runs between Baku, on the Caspian Sea, and Batum and Poti, on the Black Sea. A narrow-gage spur connects Chiaturi with Sharopan.

The manganese deposits were discovered in 1848, but were not mined until 1879. The mines are in a very mountainous country on the west slope of the Lesser Caucasus, along high cliffs on either side of Kvrilli River. They are reached by a steep trail from Chiaturi, on the banks of the river, 1½ to 3½ miles distant, and 700 to 1,050 feet lower. The following description is condensed in part from the article by Drake already cited.

Seven mountains rise with almost perpendicular slope from Kvrilli River. Four of these, Organyi, Zedorganyi, Gwimavi, and Darkvetti, are on the north bank, and three, Perivissi, Ichocrotti, and Itvissi, on the south bank. They are separated from one another by small branches of the Kvrilli. On the upper slopes of these mountains are the mines, at about equal distances above the river, and extending along it for over 2 miles. The ore occurs in a horizontal bed (fig. 33) 6 to 7 feet thick, with a slight southeasterly dip, at the contact of Eocene[a] brown sandstone with underlying Cretaceous limestone. The bed is without abrupt or extreme variations of thickness, and probably extends over an area of 22 square miles. It outcrops near the top of the cliffs along either side of the river about 1,000 feet above it.

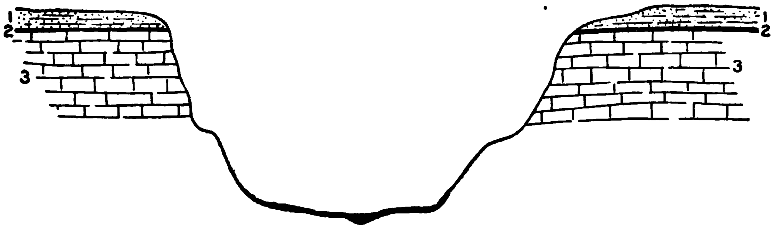

FIGURE 33.—Section showing the occurrence of manganese ores in the Sharopan district. (After Drake.) 1, Sandstone; 2, manganese ore; 3, limestone.

The deposit has a distinctly stratified structure and is composed largely of pyrolusite, though other oxides of manganese occur. The ore is concretionary and oolitic and in many places shows botryoidal surfaces and concentric structure. In many places strata of sandstone or of loose, friable arenaceous or calcareous material are intercalated with the manganese ore, and vary in thickness from a fraction of an inch to as much as 10 inches or a foot.

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[a] Stelzner and Bergeat, op. cit., p. 258.

The Chiaturi ore is high in manganese, in some places containing 50 per cent without sorting or cleaning; the average percentage is from 40 to 45. Some high-grade ores that have been thoroughly cleaned contain as much as 61 per cent manganese. The average sorted ore that is exported contains 51 or 52 per cent. Phosphorus averages about 0.16 per cent and silica not more than 8 per cent.

The physical characteristics of the ore are unfavorable, inasmuch as the proportion of large pieces obtained is small, and much of the ore is soft and grinds to a fine powder during the handling incidental to mining, cleaning, and transportation. The loss of ore is therefore considerable, and much of the fine ore that is shipped is considered objectionable by the consumers.

The following is an analysis of manganese ore from the Sharopan district:

Analysis of well-sorted and cleaned ore from Chiaturi, Russia.[a]

[Dried at 212° F.]

MnO_2	86.25	SiO_2	3.85
MnO	.47	CO_2	.63
Fe_2O_3	.61	S	.23
Cu oxide	.01	P_2O_5	.323
Ni oxide	.30	H_2O+	1.850
Al_2O_3	1.74		
CaO	1.73		99.953
MgO	.20	Mn	54.90
BaO	1.54	P	.141
K_2O and Na_2O	.22		

The mining is carried on by means of many galleries driven into the hillside along the manganese bed. They are only short distances apart along the outcrop, and cross tunnels branch from them in all directions. Few of the workings go back more than 300 feet from the face of the cliff; exceptionally they reach 400 or 500 feet. Hence only the outer edge of the ore bed has been worked. The ore is hauled from the tunnels in wheelbarrows and baskets. In a few places wooden rails have been laid and the ore is hauled out in primitive mine cars. It is taken from the mines to Chiaturi down a steep mountain trail by pack animals or on ox carts, and thence on the narrow-gage railway to Sharopan, whence it is carried on the Transcaucasian Railway to Batum and Poti, on the Black Sea.

OTHER DEPOSITS IN TRANSCAUCASIA.

Other deposits in Transcaucasia are near Choruk River in Kutais, southward from Batum and in the Governments of Tiflis, Erivan, and Elisabetpol. Ores are also reported from the stations of Samtredi and Novo-Senaki on the Transcaucasian Railway.

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[a] Drake, Frank, op. cit., p. 196.

NIKOPOL DISTRICT.

The deposits of South Russia are near Nikopol,[a] on Dnieper River, 100 miles from its entrance into the Gulf of Odessa. They were first worked in 1886. The ores are in beds about 3½ feet thick and are in Oligocene strata. The ore-bearing layer consists of sandy clay much stained by manganese, which contains nodules of psilomelane and pyrolusite with concentric or cellular structure. The hanging and foot walls of the ore bed consist of glauconitic clays, which on the foot wall are commonly sandy. The ores are but a short distance above crystalline bed rock and were probably derived from it through weathering processes. The better class of ore contains 57 per cent manganese.

The following is an analysis of manganese ore from the Nikopol district:

Analysis of manganese ore from the Nikopol district, Russia.[b]

Moisture	7.00
Mn	46.00
Fe	1.00
SiO_2	12.50
P	.25

Near Horodizce,[a] 11¼ miles north of Nikopol, there is a bed of manganese ore 6 to 10 feet thick, overlain by Tertiary clays and underlain by granite but separated from it by a bed of kaolin and sand about a foot thick. The ore consists of a mixture of quartz grains and pyrolusite nodules.

URAL MOUNTAINS.

In the Urals there are manganese deposits in the Government of Perm, in the region of the Nizhne-Taghilsk works, and also in the Government of Orenburg.

Yakovlev reports six deposits of manganese ore in the Nizhne-Taghilsk works, including the Sapalsky mines, as being spread over about 12½ miles. The ore is accompanied by brown iron ores, and occurs at or near the contact of Devonian limestones and hornblendic igneous rocks (syenite, etc.). Some of it occurs directly at the contact, but elsewhere it is entirely within the limestone or within the igneous rocks.

In three of the six deposits the limestones have been contact-metamorphosed by eruptive rocks and have been so marmorized with the obliteration of bedding planes and joints as to be practically impermeable to water, and thus form less favorable places for the deposition of manganese than the unmetamorphosed limestones. The two richest deposits are connected with limestones that have undergone such folding and fissuring as to favor the circulation of underground waters and the precipitation of ore. The ore is supposed to be connected in origin with the manganese-bearing hornblende of the igneous rocks.

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[a] Stelzner and Bergeat, op. cit., p. 259.

[b] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, 1898, p. 120.

Large deposits of rhodonite occur in crystalline schists and later argillaceous schists near the village of Ssedelnikowaja,[a] 15½ miles southeast of Jekaterinburg, in the Urals. The rhodonite is mixed with quartz and occurs as a bed about 9 feet thick in argillaceous schists. Locally veins and stains of manganite occur. The unaltered rhodonite is quarried and is used for ornamental purposes. It is polished in stone works at Jekaterinburg and St. Petersburg and is known as "orletz" in Russia.

TUNIS.[b]

Large deposits of manganese ore occur in Tunis near Ain-Mulares. The quantity available is said to reach a million tons.

CAPE COLONY.[c]

An important discovery of manganese ore has recently been made at Caledon, Cape Colony. The deposit is said to contain 30,000 tons of ore with a manganese content of 42 per cent.

EGYPT.

Manganese ores, manganiferous iron ores, and iron ores occur together in deposits in Carboniferous rocks on the Sinai Peninsula east of the Gulf of Suez.

According to Barron,[d] the Carboniferous rocks consist of two sandstones, an upper and a lower, separated by a limestone bed. The lower sandstone bed consists of a series of dark-red sandstones and shales, resting on the eroded surface of a basement consisting of gray gneiss and schist. The limestone bed is crystalline in the upper and lower parts, but in the middle has fissile, ocherous layers. The lower part is strongly stained with manganese oxides in places. The upper sandstone consists of a thick series of reddish and brownish sandstones, which is overlain by a bed of olivine basalt of contemporaneous origin. Above this are lighter-colored Cretaceous sandstones.

The ores occur in pockets 2 to 4½ feet deep in the lower crystalline limestone layer at its contact with the underlying sandstone. They are found nearly everywhere that the lower portion of the limestone is exposed. The ore varies in composition in different places from pure hematite through a mixture of hematite and manganese oxides to pure manganese oxides, mainly psilomelane. Three localities were examined by Barron—Wadi Malha, Wadi Nasb, and Wadi Halliq, all at some distance from the seacoast. In the first, manganese and iron ores lie side by side, more or less distinct from each other but intermixed at their junction. The same is true of the second locality, but there is some earthy manganese ore (wad) in addition. In the third locality hematite is more abundant than manganese oxides.

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[a] Stelzner and Bergeat, op. cit., p. 247.

[b] Manganese ore in Tunis: Review in Jour. Iron and Steel Inst., 1908, No. 3, p. 497.

[c] Manganese ore in Cape Colony: Review in Jour. Iron and Steel Inst., 1908, No. 1, p. 239.

[d] Barron, T., The topography and geology of the peninsula of Sinai: Survey Dept. Egypt., 1907, pp. 160–170, 205–207.

The principal gangue material of the ores is silica. Calcite also occurs, and limonite is associated with the hematite.

The following are analyses of ore from Wadi Malha and Wadi Halliq, showing the gradation in composition between pure hematite and pure manganese oxide:

Analyses of manganese ores from Sinai Peninsula.[a]

	Fe_2O_3.	Fe.	MnO.	MnO_2.	Mn.
Wadi Malha:					
Hematite	46.96	32.87	....	....	....
Manganese oxides	3.74	2.62	15.21	71.59	57.00
Wadi Halliq:					
Manganiferous iron ore	25.34	17.74	....	38.19	24.12
Psilomelane	....	....	41.03	45.50	60.48
Manganiferous iron ore	20.14	14.31	....	39.95	25.23
Manganese oxides	....	....	....	71.41	45.10
Manganiferous iron ore	27.60	19.32	14.60	40.81	37.03
Red ocher	32.10	22.47	....	....	....
Low-grade manganese ore	2.32	1.62	....	30.33	19.16
Manganiferous iron ore	34.24	23.97	....	29.52	18.66
Iron ore	69.34	48.54	....	3.06	1.94
Manganiferous iron ore	16.90	11.83	32.87	18.56	37.18
Hematite	98.24	68.77	....	....	....
Do	93.69	65.58	....	....	....
Do	73.62	51.53	....	9.58	6.05
Manganiferous iron ore	38.80	27.16	14.72	24.10	26.64
Low-grade iron ore	25.86	18.10	....	....	....

[a] Barron, T., op. cit., p. 206.

INDIA.[a]

DISTRIBUTION AND CHARACTER OF ORES.

Manganese ore is found in India in the Madras and Bombay Presidencies, in Central India, in the Central Provinces, in Bengal, and in Lower Burma.

In the Madras Presidency it is found in the Chipurupalle talug of the Vizagapatam district, in the Ganjam district of Kallikota State, and in the Sandur Hills of Bellary.

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[a] References on the manganese ores of India:

Fermor, L. L., Notes on the petrology and manganese-ore deposits of the Sausar tahsil, Chhindwara district, Central Provinces: Record Geol. Survey India, vol. 33, pt. 3, 1906, p. 159; Manganese-ore deposits of India: Mem. Geol. Survey India, vol. 37, 1909.

Holland, T. H., General report of the Geological Survey of India, 1905: Record Geol. Survey India, vol. 33, pt. 3, 1906, p. 65.

Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, p. 220.

Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, 1898, p. 124.

Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6, 1899, p. 154.

Mineral Resources U. S. for 1904, p. 136.

Mineral Resources U. S. for 1905, p. 106.

On the Bombay side it is found at several places around Mahabaleshwar and Yeruli, in Satara, as irregular nodules distributed through the cover of the Dekkan trap; in the southern part of the Belgaum district; in Bijapur; in Narukot; near Jambughora, in Rewa Kantha, and in the Dharwar, Panch Mahals, and Ratnagiri districts.

In Central India manganese ore is found in Jhabua State, in Gwalior State, and in several localities in the Dhar forest.

In the Central Provinces deposits have long been known at Gosalpur and Sihora, in the Jabalpur district. Recently many deposits have been discovered in the Sausar tahsil, in the Chhindwara region, among which are those of Kachi Dhana, Lakhanwara, Gaimukh, Sitapar, Bichua, Alesur, Devi, Ghoti, Wagora, Gowari Warhona, and Dudhara. Deposits also occur in the Ramtek tahsil of the Nagpur district, in the northwestern part of the Nagpur district, in the northwestern part of the Bhandara district, in the Balaghat district near the town of Balaghat and in the western part, and at Ukua, in the Behir tahsil. Ore is also reported from the States of Khairagarh and Kalahandi. Manganese and manganiferous iron ores occur in the Singhbhum district in Bengal.

In Lower Burma ore is reported in the Tavoy and Mergin districts, on the banks of the Thugo stream and Thirabuen and Great Tenasserim rivers. The ore is stated to consist of black and gray oxides and wad.

Manganese ore also occurs in Hyderabad and in the form of manganiferous iron ore near Chaibassa, in the Chota Nagpur.

Following is a general summary of results obtained by Fermor in a recent survey of the manganese deposits of India, with reference to the geologic occurrence of the ores in the localities mentioned above:[a]

> The ore occurs in three distinct forms of deposits:
>
> (*a*) Braunite, psilomelane, and pyrolusite associated with and derived from manganese-bearing silicates (such as spessartite, rhodonite, and, less frequently, piedmontite), occurring as bands and lenticles in Archean schists and gneisses. Examples of these occur in—
>
> (1) Narukot, in Bombay; manganese ores are associated with porphyritic biotite granite as an alteration of xenoliths of manganiferous rocks in these.
>
> (2) Jhabua, in Central India; manganese-ore deposits consist of much-folded alternating quartzite and manganese-ore layers associated with spessartite and rhodonite-bearing rocks.
>
> (3) Balaghat, Bhandara, Chhindwara, and Nagpur, in the Central Provinces; manganese ores are derived from the alteration of spessartite quartz rock often containing a small quantity of apatite, but usually quite free from feldspar.
>
> (4) Ganyam, in Madras; manganese ores are associated with spessartite-feldspar and spessartite-rhodonite rocks.
>
> (5) Vizagapatam, in Madras; manganese ores occur in a complex of Archean rocks in which have been intruded, as an igneous magma, manganiferous rocks containing manganese silicates, such as spessartite and manganese pyroxenes. The principal

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[a] Holland, T. H., op. cit., p. 94.

type of rock is an apatite-spessartite-feldspar rock which, under the influence of chemical waters, doubtless heated, has been decomposed and its manganese contents deposited elsewhere in the form of oxides.

(*b*) Psilomelane and pyrolusite superficially formed on outcrops of rocks of Dharwar age, consisting chiefly of quartzites, shales, slates, and hematite-schists banded with jaspery quartzite—

(1) Singhbhum, in Bengal; manganese and manganiferous iron ores, the former largely psilomelane, occur as a superficial replacement of sericitic phyllites, quartzites, and feldspathic grits.

(2) Dharwar, in Bombay; manganese ores occur on the outcrops of banded, limonitic, jaspery quartzites.

(3) Panch Mahals, in Bombay; manganese ores consist of psilomelane and pyrolusite occurring as superficial replacements of slates and quartzites.

(4) Jabalpur, in the Central Provinces; manganese ores of two classes, viz, (*a*) manganiferous iron ore and psilomelane and (*b*) pyrolusite, occur in rocks of Dharwar age; the first consists of large masses of limonite veined with psilomelane occurring as superficial alterations of hematite schists; the second occurs in nests and stringers in quartzite.

(5) Sandur Hills, in Madras.

(*c*) Psilomelane and pyrolusite associated with or contained in laterite—

(1) Belgaum, in Bombay; manganese ore occurs in spherical concretions in a deposit of laterite 15 to 20 feet thick, passing downward into quartz schist underlain by slightly manganiferous limestone which, like the quartz schist, is of Dharwar age.

(2) Satara, in Bombay; concretions of psilomelane are embedded in lateritic soil resting on Deccan trap and are probably derived from the latter by the concentration of manganese which basic lavas often contain.

(3) Jabalpur, in the Central Provinces; manganese ore (pyrolusite) occurs as nodular segregations in lateritic débris derived from the decomposition of rocks of Dharwar age.

VIZAGAPATAM DISTRICT.

The Vizagapatam district, in the Madras Presidency, was the first of the Indian manganese areas to be exploited, attention being directed to it in 1890.

The ore outcrops locally over an area of 100 square miles, situated within the extensive territories of the Maharajah of Vizianagram, stretching between the Eastern Ghats (mountains) and the Bay of Bengal. It is about 500 miles north of Madras and the same distance south of Calcutta.

The country rock is Archean granite and schist containing manganese silicates, from which the present oxide deposits are derived by weathering. The outcrops occur in a level country in the form of mounds, as low hills, and in isolated blocks; in some places the soil, impregnated with black oxide of manganese, gives indications of ore beneath. The first mound was discovered within a few hundred yards of the East Coast Railway, and the contractors broke up the manganese blocks for ballast, unaware of their nature. Investigation showed that this was but the end of a deposit of vein-like masses of ore and detached bowlders, in a detritus of country rock, about 2½ miles in length and comprising an area of 660 acres. Detached blocks of ore exhibited marks of being waterworn, and occurred in all sizes from pebbles up to bowlders of several hundredweight. These fragments were disseminated through the soil, in some places so sparsely as to make mining unprofitable, but elsewhere in beds several feet thick.

Some fragments are nodular, have a coating of iron oxide, and when broken present a steel-gray color. They contain 45 to 48 per cent manganese. Other fragments are angular, show a metallic luster, and contain 48 to 50 per cent metallic manganese. The vein-like masses have been worked to a depth of about 50 feet. They vary considerably in manganese, iron, and phosphorus content. Some of the ore is steel gray and contains 48 per cent manganese, and associated with it is a cindery ore of 35 per cent manganese.

The following is an analysis of manganese ore from the Vizagapatam district:

Analysis of ore shipped from the Vizagapatam district, India.[a]

Mn	47
Fe	9
P	0.25–0.30
SiO_2	2

JABALPUR DISTRICT.

The deposits at Gosalpur, in the Jabalpur district, have been known for a long time, and the ore has been used to a small extent by native glass makers in the neighborhood. The ore occurs in the Dharwar schist series, outcropping in a belt 7 miles wide and stretching 20 miles northeast and southwest. It is dark steel-gray, finely crystalline pyrolusite mixed with a varying proportion of psilomelane, and has the following composition:

Analysis of manganese ore from Gosalpur, India.[b]

Mn	54.66
Fe	3.17
P_2O_5	.28
MnO_2	83
Available O	15.26

A considerable amount of psilomelane also occurs with the manganiferous micaceous iron ore in the same locality.

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[a] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, p. 125.

[b] Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, p. 221.

The following are analyses of manganese ores from Gosalpur:

Analyses of manganese ores from Gosalpur, India.[a]

	Pyrolusite.	Psilomelane.	
		1.	2.
SiO_2	3.27	8.20	5.20
MnO_2	82.40	75.34	73.00
MnO	2.84		
Fe_2O_3	2.01	3.13	9.13
Al_2O_3	3.19	.14	.60
CaO	Trace.	1.66	2.40
BaO	2.94	....	....
MgO	Trace.	....	....
P_2O_5	[b].36	.39	.27
SO_2	Trace.	....	....
CO_2	....	....	....
Zn oxide	Trace.	....	....
H_2O+	2.81	7.75	7.32
Moisture	.44		
Cu oxide	....	.40	....
Co	....	.51	....
Ni	....	.16	....
	100.26	97.68	97.92
Mn	54.29	....	....

[a] Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1896, p. 221.
[b] Phosphorus, 0.16.

SAUSAR TAHSIL.

The ores of the Sausar tahsil in the Chhindwara district occur in lenticles and lenticular drawn-out bands of any thickness up to 50 or 100 feet (as at Kachi Dhana); as regards length the bands (at Wagora) have been traced at intervals for a mile. The deposits are inclosed in gneisses and schists or crystalline limestones and have the same strike and dip as those rocks. The ores commonly outcrop in hillocks. They consist mainly of braunite, psilomelane, and rhodochrosite, associated with spessartite and rhodonite, from which they are derived through processes of weathering.

The deposits of Bichua, Alesur, Devi, Ghoti, Wagora, and Dudhara consist mainly of spessartite-quartz rock with rhodonite, not sufficiently altered to form manganese-oxide deposits of commercial value. In the first three localities this rock is inclosed as bands in crystalline limestone; in the others, in biotite schist and gneiss. In some places the bands are partly altered to manganese oxides, and the inclosing limestones and schists are stained black. Rhodochrosite occurs in a few places. The bands vary in thickness and may be traced for considerable distances. In some places only single bands occur, but elsewhere a number of parallel bands are found together.

The Kachi Dhana deposit is the largest in the district, being probably 50 to 100 feet wide, and outcropping in five separate hillocks. It is composed of braunite and psilomelane associated with partly chalcedonized spessartite-quartz and magnetite-spessartite rocks.

The Lakhanwara deposit consists mainly of gray crystalline braunite. The outcrop of the Gaimukh ore body is lenticular, 180 feet long east and west, and 75 feet broad. The ore is braunite with some rhodochrosite derived from spessartite and rhodonite, much of which is still unaltered. Only the central portion of the outcrop, 60 feet long and 20 feet wide, is sufficiently altered to be workable. The Sitapar deposit forms a hillock consisting of huge blocks containing a great variety of manganese minerals.

The Gowari Warhona deposit consists of a stratum 5½ to 6 feet thick and one-fourth mile long, dipping 50° S. 30° W. The ore is bedded in layers 1 to 4 inches thick. Outside of the limits mentioned, the ore grades into spessartite-quartz rock. In all of these localities the ore bodies occur in mica schist and gneiss.

Following are analyses of ores from the Sausar tahsil in the Chhindwara district:

Analyses of manganese ore from Sausar tahsil, Chhindwara, India.[a]

Locality.	Mn.	Fe.	SiO_2.	P.	Moisture at 100° C.
Kachi Dhana	54.73	5.00	6.99	0.07	0.17
Do	53.25	....	....	.91	.26
Do	51.87	4.92	16.27	.033	....
Do	53.05	2.82	1.10	.004	....
Do	56.82	5.30	9.02	.135	....
Lakhanwara	50.41	11.77	4.86	.20	.39
Do	57.51	6.02	4.63	.153	....
Gaimukh	54.98	6.19	10.63	.04	.32
Do	56.68	6.21	7.68	.078	....
Do	54.20	5.00	9.75	1.036	....
Sitapar	54.97	6.89	6.95	.06	.00
Do	54.57	7.03	7.90	.12	.04
Do	54.94	5.28	7.33	.072	....
Do	53.90	6.10	8.37	.055	....
Devi	48.95	7.03	4.98	.28	1.27
Ghoti	49.55	7.71	8.74	.28	.52
Do	48.62	8.17	6.28	.276	....
Do	49.48	8.25	4.60	.306	....
Wagora	29.08	6.88	36.63	.15	.86
Gowari Warhona	53.59	5.00	6.21	.07	.31
Do	51.82	1.31	1.45	.03	....
Do	56.45	3.83	10.10	.09	....
Do	47.45	3.55	13.65	.122	....

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[a] Fermor, L. L., Notes on the petrology and manganese-ore deposits of the Sausar tahsil: Record Geol. Survey India, vol. 33, pt. 3, 1906, pp. 209, 214.

OTHER DISTRICTS.

In the Nagpur and Balaghat districts manganese ore occurs as lenticular masses and bands in quartzites, schists, and gneisses. Some of the ore bodies are very long and wide. At Balaghat one deposit is 1¾ miles long; at Manegaon, in the Nagpur district, the ore body is 1½ miles long; and at Thiroi, in the Balaghat district, the deposit is nearly 6 miles long. At Kandri a deposit of pure ore is 100 feet wide, and at Ramdongri a body of mixed ore and spessartite rock is as much as 1,500 feet wide.

CEYLON.[a]

Small deposits of manganese ore containing 1.61 per cent of cobalt occur at Ampituja, Ceylon.

JAPAN.[b]

Moderate quantities of manganese oxide are mined yearly in Japan, but the deposits are not extensive. The ores occur in the mountainous districts, are mined from shallow surface workings, and are carried down in small quantities by the natives. The chief exports are from the ports of Yokohama, Kobe, and Osaka.

Alabandite associated with rhodochrosite occurs in large quantities in the silver veins at Innai, in the Province of Akita.[c]

The following are analyses of manganese ores from Japan:

Analyses of Japanese manganese ores.[a]

	1.	2.	3.	4.
Mn oxide	87.3	71.9	71.7	
Mn				49.00
SiO_2	1.4	15.25	2.09	8.50
Fe_2O_3	3.47			
Al_2O_3	.43	4.44	6.17	
SO_3	.04	.03	.06	
P_2O_5	.201	.07	.29	
P				.09
H_2O	1.25	2.05	2.30	
Moisture				9.00

[a] Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, 1898, p. 123.

OCEANIA.

PHILIPPINE ISLANDS.[d]

Manganese deposits are found in the Philippine Islands in the Provinces of Ilocos Norte and Tarlac, on Luzon Island, and on Masbate Island. In Ilocos Norte the ores occur as nodules on the surface, derived from the weathering of veins. On Masbate Island and in Tarlac they occur as bowlders in bedded deposits apparently residual.[e]

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[a] Dunstan, W. R., Manganese: Rept. Results Mineral Survey Ceylon, 1903-4, p. 8.

[b] References on the manganese ores of Japan:
Mineral Resources U. S. for 1893, p. 152.
Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 451.
Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 6, 1898, p. 122.
Mineral Resources U. S. for 1903, p 154.

[c] Stelzner, A. M., and Bergeat, A., Die Erzlagerstätten, pp. 716-717.

[d] References on the manganese deposits of the Philippine Islands:
Smith, W. D., The asbestos and manganese deposits of Ilocos Norte, with notes on the geology of the region: Philippine Jour. Sci., vol. 2, June, 1907, p. 145.
Smith, W. D., Nonmetallic minerals: Far Eastern Review, June, 1907, p. 10.
McCaskey, H. D., unpublished notes.

[e] McCaskey, H. D., unpublished notes.

The Masbate Island deposit is in the Arparoy mining district in the northern part of the island. The ores are argentiferous and occur as nodules in reddish shales. They have the following composition:

Analysis of manganese ore from Masbate Island, Philippines.[a]

Mn	59.77
SiO_2	10.41
P	.027
S	.037
Au	Trace.
Ag (ounces)	44

The deposit in Tarlac Province is on the road between Capiz and Iba. Both of these bedded deposits are undeveloped and their extent is unknown.

The deposits of Ilocos Norte are near Nagpartian, in the northern part of the province. The following succession of rocks is given for this region by Smith:[b]

Succession of rocks in Ilocos Norte, Philippines.

Raised coral reefs.
Marl beds with recent shells.
Orbitoidal limestone.
Sandy shales and tuff beds alternating.
    Andesite flows and "eruptive conglomerate."
Pasuquin calcareous sandstone.
Baruyen series, coarse-grained sandstones, and shales alternating.
    Ferruginous cherts and slates, jasper.
Granulite dikes.
Crystalline schists; serpentinized pyroxenite.

The pyroxenite and crystalline schists were formed by the regional metamorphism of a diorite batholith and associated sediments, and by the intrusion of granulite dikes. They constitute the basement upon which other comparatively unaltered sediments and volcanic rocks were deposited. The only volcanic rocks present in the overlying sediments are a series of tuffs, andesite flows, and eruptive conglomerates near the middle of the section.

The manganese ores occur in a region underlain by the "eruptive conglomerate." This rock consists of masses of lava fragments with a soft tuff-like matrix, also volcanic. The fragments are porphyritic, the phenocrysts being mainly plagioclase and augite, with some magnetite. In origin the rock is probably closely related to the andesite flows and the tuff beds in the same series.

Flattened nodules of pyrolusite and limonite, one-half to 2 or 3 inches in diameter, scattered over the surface, form the principal deposits. These are derived from the disintegration of small manganese and iron-oxide veins in the matrix between the hard fragments in the underlying eruptive conglomerate. The veins are 5 to 50 millimeters wide and occur locally in the matrix, penetrating it in different directions.

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[a] McCaskey, H. D., unpublished notes.

[b] Smith, W. D., Philippine Jour. Sci., vol. 2, 1907, p. 170.

The most important of the deposits is between Punta Negra and Punta Blanca, close to the sea. Here 2 feet of pyrolusite surface concentrates occur on the surface of the eruptive conglomerate in a depression between outcrops of the overlying Orbitoidal limestone. Underneath the deposits is a thin layer of limonite.

The following is an analysis of ore from this region:

Analysis of manganese ore from Ilocos Norte, Philippines.[a]

SiO_2	1.10
Fe_2O_3	4.04
MnO_2	77.51
H_2O	10.58
P_2O_5	.02
	93.25
Mn	48.93

JAVA.[b]

Manganese deposits have been exploited in the regencies of Pegasin and Mongolaen, in Java, and a small amount of ore has been shipped from the island.

BORNEO.[c]

Considerable deposits of manganese ore were recently discovered at Taritipan, in Maruda Bay, British North Borneo.

NEW ZEALAND.[d]

The manganese ores of New Zealand consist mainly of braunite and wad, with pyrolusite here and there in small quantities. Small amounts of rhodonite also are found. The principal work has been done near Russell and at Waiheki, a considerable distance north of Russell. The ore here contains 75 per cent oxide of manganese. At the Bay of Islands, Napier, an ore with 45 per cent manganese is found.

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[a] Smith, W. D., Philippine Jour. Sci., vol. 2, 1907, p. 170.

[b] Mineral Resources U. S. for 1903, p. 155.

[c] Manganese ore in Borneo (Review): Jour. Iron and Steel Inst., 1907, No. 3, p. 329.

[d] References on the manganese ores of New Zealand:
Mineral Resources U. S. for 1886, p. 207.
Mineral Resources U. S. for 1893, p. 154.
Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 452.

AUSTRALIA.[a]

In Australia there are manganese deposits in New South Wales, South Australia, and Queensland.

NEW SOUTH WALES.

The ores of New South Wales are brown and black oxides, which contain on an average 40 to 50 per cent of metallic manganese but may run as high as 53 per cent. They are found in the Bathurst and Bendemeer districts.

SOUTH AUSTRALIA.

Ores of the following composition occur near Gordon, South Australia:

Analysis of manganese ore from South Australia.[b]

Mn	39.68
Fe	24.08
P_2O_5	.08
S, SiO_2, and moisture	Trace.

QUEENSLAND.

The principal manganese deposits in Queensland are in the Gladstone district, extending from Targinie on the northwest to Calliope on the south, and Quoin Island, on the east. It has, roughly, as its greatest dimensions a length of 15 miles and a width of 12 miles.

The area consists of massive slates, quartzites, jasperoids, and sandy clay schists, variously intersected by dikes of trachyte, syenite, and diorite, and locally overlain by river and estuarine alluvials.

The typical country rock for manganese is hard, flinty, red or brown, in places quartz-veined, jasperoid clay slate, indurated and colored, owing to partial or complete replacement by silica and oxides of iron. These indurated rocks pass at 20 to 50 feet in depth into soft brown or yellow clay, slate (or schist), or bluish quartzite.

The deposits are lenticular, lying, with very few exceptions, with their longer axes parallel to the bedding of the slates. As a rule, the outcrop is small, and the work thus far indicates that the depth of the lenses is no greater than their greatest length. There are probably a number of overlapping lenses, extending to a considerable depth. The deposits may be considered to form belts running about north and south, with a tendency to north-northwest, parallel to the strike of the rocks. One deposit (in the Mount Miller mine) is 3 to 21 feet thick.

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[a] References on the manganese ores of Australia:
Mineral Resources U. S. for 1886, p. 207.
Mineral Resources U. S. for 1893, p. 153.
Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 452.
Mineral Resources U. S. for 1904, p. 137.

[b] Mineral Resources U. S. for 1886, p. 207.

The typical ore is chiefly psilomelane, but contains pyrolusite and probably also braunite. It is massive and mostly steel-gray, passing into dull bluish in bands and patches. In some places it is honeycombed, and there the cavities are lined with a dead-black deposit of binoxide.

The following analyses of ore from the Gladstone district show the limits between which the composition varies:

Analyses of manganese ore from the Gladstone district, Queensland.[a]

	1.	2.
Mn	30.3	48.7
Fe	1.2	7.2
SiO_2	5.8	15.3
P	Trace.	.11
S	Trace.	....

[a] Mineral Resources U. S. for 1904, p. 138.

Manganese occurs at Auckland Hill, Queensland, in bunches of 20 or 30 tons connected by stringers. In this locality it has replaced slate. The ore is a mixture of psilomelane, pyrolusite, and braunite, massive and steel-gray, having the following composition:

Analyses of manganese ore from Auckland Hill, Queensland.[a]

MnO_2	69.4
SiO_2	7.6
Fe	2.2
P	.33
S	Trace.
Mn	46.7

Manganese ore occurs in Queensland, also in the district between Rockhampton and Emu Park, in the Ipswich district, in the Hodgkinson district, in the parish of Rosenthal, and at Mount Gammie in the Darling Downs district.

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[a] Mineral Resources U. S. for 1904, p. 139.

CHAPTER IV.

CHEMISTRY OF MANGANESE.[a]

METALLIC MANGANESE AND ITS ALLOYS.

Manganese is a white or grayish-white metal having the appearance of cast iron, but possessing a reddish luster like bismuth. It is very hard and brittle, has a specific gravity between 7.13 and 8, and an atomic weight of 54.6 ($H=1$) or 54.93 ($O=16$). Manganese oxidizes readily and is never found free in nature. It crumbles when exposed to the air, is soluble in dilute acids, and decomposes warm water with the evolution of hydrogen. It melts at about 1,900° C.

The various processes for the preparation of manganese may be arranged in three groups,[b] namely:

1. Reduction of the oxides or salts with sodium, magnesium, aluminum, hydrogen, or iron sulphide.
2. Electrolysis of manganese salts.
3. Carbon reduction (*a*) in gas or coke-fired furnaces, or (*b*) in electric furnaces.

By the first two methods the pure metal is produced, while by the third impure alloys are obtained which contain admixtures of carbon, silicon, or iron.

The original process for the preparation of manganese, proposed by John in 1807,[c] consists in reducing the oxide produced by the calcination of the carbonate, by mixing it with carbon and oil, covering the mixture with charcoal in a charcoal-lined crucible, and heating it to high temperature. The metal produced contained considerable carbon and silicon from the charcoal, but by further ignition with borax a very pure metal was obtained.

Sainte-Claire Deville[d] reduced Mn_3O_4 with sugar charcoal and obtained a regulus coated with a violet crystalline mass, which appeared to be calcium manganese spinel, $CaO.Mn_2O_3$.

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[a] References on the chemistry of manganese used in the preparation of this chapter:
Roscoe, H. E., and Schorlemmer, C., A treatise on chemistry, vol. 2, 1907, p. 1096.
Newth, G. S., Text-book of inorganic chemistry, 1908, pp. 666-670.
Moissan, H., Traite de chimie minérale, IV, Métaux: Manganese, p. 487.

[b] Roberts, Edwin G. Ll., and Wraight, Ernest A., The preparation of carbon-free ferromanganese: Jour. Iron and Steel Inst., London, 1906, No. 2, p. 239.

[c] John, J. F., Contributions toward a chemical knowledge of manganese: Thomson's Annals of Philosophy, vol. 2, 1813.

[d] Sainte-Claire Deville, M. H., Mémoire sur la production des températurs très élevées: Annales chim. phys., vol. 46, 1856, p. 199.

Tamm[a] suggested the following method for its preparation: A flux is prepared of twenty parts of powdered soda-lime glass and seven parts of fluorspar, and is added to one part of lampblack and eleven parts of manganese oxides. The material is heated to a white heat in a plumbago crucible lined with a mixture of graphite and fire clay. A green slag and metallic manganese are produced. The slag is used as flux for further smelting operations. The metal contains a variety of impurities which may be largely removed by fusion with half its weight of manganese carbonate.

The following are analyses of the impure regulus and the pure form of the metal:

Analyses of metallic manganese.[a]

	1.	2.
Mn	96.90	99.910
Fe	1.05	.050
Si	.85	.015
C	.95	.025
Al	.10	....
Ca	.05	....
P	.05	....
S	.05	....
	100.00	100.000

[a] Roscoe and Schorlemmer, op. cit., p. 1099.

By reduction in a blast furnace, manganese of the following composition has been obtained: Manganese, 85 per cent; iron, 8 per cent; carbon, 6 per cent; silicon, phosphorus, and sulphur, traces.

Manganese has also been prepared by igniting a mixture of fluorspar and manganese chloride with metallic sodium, or by gradually adding metallic magnesium to a mixture of manganese chloride and potassium chloride.

The preparation of the metal by reduction with aluminum has received considerable attention, and high-grade products have been produced. By this method powdered aluminum and manganese oxide are mixed together in equivalent proportions, forming what is known as manganese thermite. This is ignited with a barium oxide cartridge; after the reduction molten metallic manganese occupies the lower part of the crucible with a slag of alumina (Al_2O_3) above it.

When the oxides of manganese are heated in a stream of hydrogen at a white heat they are reduced to the metal, but at a red heat only the lower oxide is formed. Moissan, by using excess of the oxide, has prepared metallic manganese free from carbon and silicon in the electric furnace.

Alloyed with iron, as in ferromanganese, manganese steel, spiegeleisen, silicospiegel, and silicomanganese, manganese may be obtained by the reduction of the oxides with carbon in the ordinary blast furnace or in the electric furnace. These products contain considerable carbon and some silicon. Cupromanganese, an alloy of copper and manganese, is obtained by the reduction of the oxides of these metals in a graphite crucible or reverberatory furnace. Other alloys, such as manganese bronze, manganese brass, and manganese German silver are commonly obtained by mixing cupromanganese with metals such as zinc, tin, aluminum, and others. Manganese amalgam, an alloy of manganese and mercury, is prepared by electrolysis. More complete descriptions of the alloys are given in the chapter on the uses of manganese (p. 243).

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[a] Tamm, Hugo, Chem. News, 1872, p. 111.

MANGANESE COMPOUNDS.[a]

MANGANESE OXIDES, HYDRATES, AND ACIDS.

List of manganese oxides, hydrates, and acids.

Manganese monoxide (manganous oxide) (basic)	MnO
Manganous hydrate	$Mn(OH)_2$
Red manganese oxide (mangano-manganic oxide) (basic)	Mn_3O_4
Manganese sesquioxide (manganic oxide) (basic)	Mn_2O_3
Hydrous manganic oxide	$Mn_2O_3.H_2O$
Manganese dioxide (manganese peroxide) (weakly acid)	MnO_2
Hydrous manganese peroxide	$MnO_2.2H_2O$
Manganese oxides	Mn_2O_5 Mn_3O_8 Mn_4O_{11}
Manganese trioxide (acid)	MnO_3
Manganese heptoxide (acid)	Mn_2O_7
Permanganic acid	$HMnO_4$
Manganese tetroxide	MnO_4

DOUBLE OXIDES.

Manganese-magnesium spinel	$Mn_2O_3.(Mn,Mg)O$
Manganese-cadium spinel	$Mn_2O_3.(Mn,Cd)O$
Manganese-zinc spinel	$Mn_2O_3.ZnO$
Manganese-aluminum spinel	$MnO.Al_2O_3$
Manganese-iron oxides	$MnO.Fe_2O_3$ $8MnO_2.3Fe_2O_3$ $Mn_2O_3.Fe_2O_3.2H_2O$ Etc.

Manganous oxide and manganic oxide give rise to manganous and manganic salts, respectively. Mangano-manganic oxide yields with acid both manganous and manganic salts or a mixture of the two. Manganese dioxide gives manganous salts with the elimination of available oxygen, and also, by combining with certain basic oxides of other metals, forms unstable compounds called manganites. Manganese trioxide and manganese heptoxide give rise to manganates and permanganates, respectively.

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[a] In the tables showing the composition of compounds of manganese the names of the most important compounds are printed in italic.

In the formation of manganous and manganic salts, manganese acting as a metal unites with the halogens to form chlorides, fluorides, bromides, iodides, chlorates, bromates, and iodates; with sulphur to form sulphides, sulphites, and sulphates; with selenium to form selenides, selenites, and selenates; with nitrogen to form nitrides and nitrates; with phosphorus to form phosphides, phosphites, and phosphates; with arsenic to form arsenides, arsenites, and arsenates; with antimony to form antimonide and antimonates; with vanadium to form vanadates; with boron to form borides, borates, and boracites; with carbon to form carbides and carbonate; with cyanogen to form cyanides and a thiocyanate; and with silicon to form silicides and silicates; with titanium to form titanates; with tin to form stannates, and with zirconium to form zirconates. Manganese forms double salts with all the principal metals, such as potassium, sodium, calcium, magnesium, barium, zinc, etc. Compounds of manganese with organic acids such as acetates are also well known.

In the formation of manganites, manganates, and permanganates, manganese acts as a nonmetal, or rather as an electro-negative element uniting with oxygen to form the acid radicle in salts in which the bases are potassium, sodium, calcium, barium, or other metals. Manganites may be regarded as salts of hypothetical manganous acid; manganates, as salts of hypothetical manganic acid (H_2MnO_4); and permanganates, as salts of permanganic acid ($HMnO_4$), an unstable, deep-red liquid.

Manganese monoxide (MnO) is a light-green powder obtained by igniting a mixture consisting of equal parts of manganous chloride and sodium carbonate, with some ammonium chloride, or by heating higher manganese oxides or the carbonate in a stream of hydrogen. It has been found in Sweden as the mineral manganosite.

When solutions of potassium hydroxide and a manganous salt are mixed, air being excluded, manganous hydroxide, $Mn(OH)_2$, is obtained as a white precipitate, which readily oxidizes and turns brown on exposure to air. It occurs in Sweden as the mineral pyrochroite.

Manganous salts (MnR'_2) are abundant. They are generally faintly pink, but this color may be due to a slight admixture of manganic salts.

Mangano-manganic oxide (Mn_3O_4) is the most stable of the manganese oxides, being formed both when higher and when lower oxides are strongly heated. Thus when the dioxide is heated oxygen is given off, and the red oxide remains; and when the monoxide is heated in air and oxygen is absorbed the same compound is formed. When prepared thus it appears as a brownish-red powder, which may be crystallized by heating gently in a slow current of gaseous hydrochloric acid. It is also obtained by heating mixtures of manganese sulphate and potassium sulphate, or of manganous oxide and calcium chloride, to bright redness. When the red oxide is treated with cold acids a mixture of manganous and manganic salts is produced; but when it is heated with dilute acids manganous salts and manganese peroxide are formed. Thus Mn_3O_4 might be considered either as a mixture of MnO and Mn_2O_3 or of 2MnO and MnO_2. Mangano-manganic oxide is found in nature as the mineral hausmannite.

Manganic oxide (Mn_2O_3) is obtained as a black powder when manganic hydrate, formed from the oxidation of manganous hydrate, is heated, or when any of the oxides of manganese are heated in oxygen. In nature it is found as the basic silicate, braunite, $3Mn_2O_3.MnSiO_3$.

Manganic hydrate, $Mn_2O_3.H_2O$ or MnO(OH), occurs in nature as a black mineral, manganite. When this is heated at 270° to 310° C. it is converted into the dioxide without change of form. Artificially, manganic hydrate is obtained as a dark-brown powder from the oxidation of manganous hydrate in moist air, or by passing chlorine into water in which an excess of manganese carbonate is suspended.

The manganic salts, MnR'_3 and $Mn_2R''_3$, are very unstable and are strongly colored. They are not as abundant as manganous salts.

Manganese peroxide (MnO_2) is found in nature as polianite and pyrolusite and with other oxides, water, and impurities as psilomelane. Artificially manganese peroxide may be prepared as black powder or fragments by melting manganous nitrate and heating it until red fumes appear and the lower oxides are deposited. The clear liquid, after being decanted, is heated for forty to sixty hours at 150° to 160° C. and manganese dioxide is deposited. Manganous carbonate, when it is heated to 260° C. in the presence of air and the residue is treated with hydrochloric acid, leaves pure manganese dioxide. When manganese dioxide is heated it loses its oxygen, changing first to Mn_2O_3, and finally to Mn_3O_4.

A compound approximating in composition to hydrated manganese peroxide may be obtained by the action of oxidizers like potassium permanganate or sodium hypochlorite on manganous salts. As it readily loses part of its oxygen, or combines to form manganites, the pure hydrated peroxide is almost impossible to prepare. It commonly consists of mixtures like $xMnO+yMnO_2+zH_2O$. Hydrated manganese dioxide in which part of the water is replaced by barium oxide occurs in nature as the mineral psilomelane.

Manganese trioxide (MnO_3) is obtained as a reddish amorphous mass by dropping a solution of potassium permanganate in sulphuric acid on dry sodium carbonate:

$$2(MnO_3)SO_4 + 2Na_2CO_3 = 2Na_2SO_4 + 2MnO_3 + 2CO_2 + O_2.$$

It is carried forward by the carbon dioxide as pink fumes and may be deposited on fragments of glass in a freezing mixture. It decomposes in water with the formation of permanganic acid and manganese dioxide.

Manganese heptoxide (Mn_2O_7) is obtained on the addition of water to a solution of potassium permanganate in concentrated sulphuric acid:

$$2KMnO_4 + 2H_2SO_4 = (MnO_3)_2SO_4 + K_2SO_4 + 2H_2O.$$
$$(MnO_3)_2SO_4 + H_2O = Mn_2O_7 + H_2SO_4.$$

The salt decomposes with the formation of green oily drops, which dissolve in the acid and produce an olive-green solution, from which the heptoxide separates out as a dark reddish-brown liquid on the addition of water.

Permanganic acid ($HMnO_4$) is obtained in solution when a requisite amount of dilute sulphuric acid is added to barium permanganate, or when any manganous salt, except the haloid compounds, is warmed with nitric acid and lead dioxide, or with dilute sulphuric acid and potassium bromate. The solution is deep-red and exhibits a blue color by reflected light. On exposure to light, or when gently heated, it gives off oxygen and the hydrated dioxide separates out. It is a strong oxidizing agent.

MANGANESE AND THE HALOGENS.

List of manganese halogen salts.

Manganous chloride	$MnCl_2$
Hydrous manganous chlorides	$MnCl_2.5H_2O$ $MnCl_2.4H_2O$ $MnCl_2.2H_2O$ $3MnCl_2.5H_2O$
Manganous bromide	$MnBr_2$
Hydrous manganous bromides	$MnBr_2.6H_2O$ $MnBr_2.4H_2O$ $MnBr_2.H_2O$
Manganous fluoride	MnF_2
Manganous iodide	MnI_2
Hydrous manganous iodides	$MnI_2.4H_2O$ $MnI_2.2H_2O$ $MnI_2.H_2O$
Manganese oxychlorides	$MnO.MnCl_2$ $3MnO.MnCl_2$ $3Mn_2O_3.MnCl$
Manganese oxyfluorides.	
Manganous chlorate.	
Manganous perchlorate.	
Manganous bromate.	

Manganous iodate	$MnIO_3$
Mangano-manganic fluoride (hydrous)	$Mn_3F_8.10H_2O$
Manganic chloride	Mn_2Cl_6
Manganic fluoride	Mn_2F_6
Hydrous manganic fluoride	$Mn_2F_6.6H_2O$
Manganic iodate	$Mn(IO_3)_6$
Manganese tetrachloride	$MnCl_4$
Manganese perbromide.	
Manganese tetrafluoride	MnF_4
Manganese periodide.	
Manganese heptochloride.	
Permanganic oxychloride	MnO_3Cl
Permanganic oxyfluoride	MnO_3F

DOUBLE SALTS.

Manganese-potassium chloride	$MnCl_4.2KCl$
Manganese-potassium chlorides (hydrous)	$MnCl_2.KCl.2H_2O$ $MnCl_5.2KCl.H_2O$
Manganese-ammonium chloride (hydrous)	$MnCl_2.NH_3Cl.2H_2O$
Manganese-lithium chloride (hydrous)	$MnCl_2.LiCl.6H_2O$
Manganese-magnesium chloride and bromide (hydrous).	
Manganese-cadmium chloride (hydrous)	$MnCl_2.2CdCl_2.12H_2O$
Manganese-cæsium chloride	$MnCl_2.2CsCl$
Manganese-cæsium chloride (hydrous)	$MnCl_2.2CsCl.nH_2O$
Manganese-rubidium chloride (hydrous)	$MnCl_2.2RbCl.2H_2O$
Manganese-potassium fluorides (anhydrous and hydrous)	$Mn_2F_6.4KF.2H_2O$ $MnF_4.2KF$
Manganese-ammonium fluorides	$Mn_2F_6.4NH_3F_4$ $MnF_4.2NH_3F$
Manganese-sodium fluoride	$Mn_2F_6.4NaF$
Manganese-nickel fluoride.	
Manganese-zinc fluoride (hydrous)	$Mn_2F_6.2ZnF_2.8H_2O$
Manganese-potassium iodate	$Mn(IO_3)_4.2KIO_3$
Manganese-ammonium iodate	$Mn(IO_3)_4.2NH_3IO_3$
Manganese-barium iodate	$Mn(IO_3)_4.Ba(IO_3)_2$

Manganous chloride is obtained by dissolving any of the oxides or the carbonate in hydrochloric acid and evaporating, $MnCl_2.4H_2O$ being deposited in pink crystals, which may be made anhydrous by heating in a stream of hydrochloric acid. It is also prepared by burning the metal in chlorine gas, or by passing hydrochloric acid over the heated carbonate. Various hydrated manganous chlorides exist. Manganous chloride forms double salts with the chlorides of other metals.

Manganous bromide ($MnBr_2$) is a pale-red solid obtained by heating the powdered metal in bromine vapor; the hydrated form ($MnBr_2.4H_2O$) is obtained by dissolving the carbonate in hydrobromic acid and evaporating the solution.

Manganous fluoride (MnF_2) is obtained by dissolving metallic manganese or the carbonate in hydrofluoric acid. On evaporation the fluoride is deposited as a white crystalline powder. It is obtained as a rose-colored mass by the action of hydrogen fluoride on manganese. Manganese fluoride is insoluble in water, but dissolves in strong acids.

Manganous iodide (MnI_2) is obtained by the dehydration of the hydrated salts in a vacuum. The hydrated salts are obtained as rose-red crystals by dissolving the carbonate in hydroiodic acid.

Manganic chloride is obtained in a dark solution by dissolving any of the oxides, Mn_3O_4, Mn_2O_3, or MnO_2, in cold concentrated hydrochloric acid. From this solution it has never been isolated, but it is supposed to have the composition Mn_2Cl_6. The solution yields double salts of the type $Mn_2Cl_6.2R'Cl$ with potassium and ammonium. When the solution is heated chlorine is evolved and manganous chloride remains.

Manganic fluoride (Mn_2F_6) is obtained in purple pseudomorphs after manganous iodide by the action of fluorine on the iodide. It is decomposed by heat into manganous fluoride and fluorine, dissolves in acids, and is decomposed by water. The hydrated fluoride ($Mn_2F_6.3H_2O$) is obtained in ruby-red crystals by dissolving the oxides, Mn_2O_3 or MnO_2 in hydrofluoric acid.

Manganese tetrafluoride (MnF_4) has been obtained by dissolving the dioxide in concentrated hydrofluoric acid. It has energetic oxidizing properties and is a decolorizer.

Manganese tetrachloride ($MnCl_4$) has been obtained as a green solution by the action of hydrochloric acid gas on manganese dioxide in the presence of alcohol or ether. A blue solution has been obtained by other methods of formation.

Permanganic oxychloride (MnO_3Cl) is obtained by gradually adding fused sodium chloride to a solution of potassium permanganate in concentrated sulphuric acid. It is evolved as yellow gas and is condensed by a freezing mixture to a greenish-brown liquid, which, when exposed to the air, emits a purple-red vapor. When heated it explodes violently, and water decomposes it into permanganic and hydrochloric acids. The corresponding oxyfluoride (MnO_3F) is also known.

Manganese chlorides form double salts with alkaline chlorides. A dark crystalline precipitate of potassium manganichloride ($MnCl_4.2KCl$) is prepared by boiling potassium permanganate with glacial acetic acid and saturating the resulting reddish-brown solution with hydrochloric acid.

Manganese fluorides form double salts with the alkali fluorides. Potassium manganifluoride ($MnF_4.2KCl$) is obtained in golden-yellow hexagonal tablets by dissolving potassium manganite in a mixture of hydrofluoric acid and potassium fluoride. It is decomposed by water, and is dissolved by hydrochloric acid into a dark-brown solution. A rubidium salt of similar nature has been prepared.

MANGANESE AND SULPHUR.

List of sulphur compounds of manganese.

Manganese monosulphide	MnS
Hydrous manganese monosulphide	$MnS.nH_2O$
Manganese oxysulphide	$MnS.MnO$
Manganese sulphites (hydrous)	$MnSO_3.3H_2O$
	$MnSO_3.2H_2O$
	$MnSO_3.H_2O$
Basic manganese sulphite	$5MnSO_3.2Mn(OH)_2.nH_2O$
Manganese hyposulphite	MnS_2O_3
Manganous sulphate	$MnSO_4$
Hydrous manganous sulphates	$MnSO_4H_2O$
	$MnSO_4.2H_2O$
	$MnSO_4.3H_2O$
	$MnSO_4.4H_2O$
	$MnSO_4.5H_2O$
	$MnSO_4.6H_2O$
	$MnSO_4.7H2O$
Acid manganese sulphates	$MnH_2(SO_4)_2$
	$MnH_6.(SO_4)_4$
Basic manganese sulphate	$3MnO.2SO_3.3H_2O$
Manganese dithionate (hydrous)	$MnS_2O_6.nH_2O$
Mangano-manganic sulphide	Mn_3S_4
Manganese bisulphide	MnS_2
Sulphate of manganese dioxide.	
Manganic sulphite	$Mn_2(SO_3)_3$
Manganic sulphate	$Mn_2(SO_4)_3$
Acid manganic sulphate	$Mn_2(SO_4)_3.H_2SO_4.4H_2O$

DOUBLE SALTS.

Manganese-potassium sulphide	$2Mns.K_2S$
Manganese-sodium sulphide	$nMnS.Na_2S$
Manganese-potassium sulphite	$MnSO_3.K_2SO_3$
Manganese-ammonium sulphite	$MnSO_3.(NH_3)_2SO_3$
Manganese-sodium sulphite	$4MnSO_3.Na_2SO_3$
Manganese-sodium sulphite (hydrous)	$MnSO_3.Na_2SO_3.H_2O$
Manganese-sodium hyposulphite (hydrous)	$MnS_2O_3.2Na_2S_2O_3.16H_2O$
Manganese-potassium sulphates (anhydrous and hydrous)	$MnSO_4.K_2.SO_4$
	$2MnSO_4.K_2SO_4$
	$MnSO_4.K_2SO_4.4H_2O$
	$MnSO_4.K_2SO_4.2H_2O$
	$Mn_3(SO_4)_2.K_2SO_4.3H_2O$
	$Mn_2(SO_4)_3.K_2SO_4$
Manganese-ammonium sulphates (anhydrous and hydrous)	$MnSO_4.(NH_3)_2SO_4.6H_2O$
	$2MnSO_4(NH_3)_2.SO_4$
	$Mn_3(SO_4)_2.NH_3HSO_4.3H_2O$
	$Mn_2(SO_4)_3.(NH_3)_2SO_4$
Manganese-sodium sulphates (hydrous)	$MnSO_4.Na_2SO_4.2H_2O$
	$MnSO_4.Na_2SO_4.4.H_2O$
	$Mn_3(SO_4)_2.Na_2SO_4.5H_2O$
Manganese-magnesium sulphates (hydrous)	$MnSO_4.MgSO_4.21H_2O$
	$MnSO_4.MgSO_4.(NH_3)_2SO_4.12H_2O$

Manganese-zinc sulphate (hydrous)	$(MnZn)SO_4.nH_2O$
Manganese-zinc-ammonium, potassium, or magnesium sulphates (hydrous)	$MnSO_4.ZnSO_4.2R'_2SO_4.12H_2O$
Manganese-aluminum sulphates (anhydrous and hydrous)	$MnSO_4.Al_2(SO_4)_3.25H_2O$ $Mn_2(SO_4)_3.Al_2(SO_4)_3$
Manganese-cobalt-potassium or ammonium sulphates (hydrous)	$MnSO_4.CoSO_4.2R'_2SO_4.12H_2O$
Manganese-iron sulphates (anhydrous and hydrous)	$MnSO_4.FeSO_4.2H_2O$ $(Mn,Fe)SO_4.5H_2O$ $MnSO_4.Fe_2(SO_4)_3.3H_2SO_4$ $Mn_2(SO_4)_3.Fe_2(SO_4)_3$
Manganese-iron-potassium or ammonium sulphates (hydrous)	$MnSO_4.FeSO_4.2R'_2SO_4.12H_2O$
Manganese-iron-zinc sulphate (hydrous)	$5MnSO_4.FeSO_4.ZnSO_4.28H_2O$
Manganese-cæsium sulphate (hydrous)	$MnSO_4.Cs_2SO_4.6H20$
Manganese-rubidium sulphates (anhydrous and hydrous)	$MnSO_4.Rb_2SO_4.6H_2O$ $MnSO_4.Rb_2SO_4.2H_2O$ $MnSO_4.Rb_2SO_4$ $2MnSO_4.Rb_2SO_4$
Manganese-ammonium dithionate.	
Manganese-potassium alum.	
Manganese-ammonium alum.	
Manganese-cæsium alum	$Mn_2(SO_4)_3.Cs_2SO_4.24H_2O$
Manganese-rubidium alum	$Mn_2(SO_4)_3.Rb_2SO_4.24H_2O$

Manganese monosulphide (MnS) occurs in nature in steel-gray crystals having a green streak, as the mineral alabandite. Artificially it is prepared as a dark-gray powder by heating the monooxide, carbonate, or sulphate in a current of hydrogen sulphide. At a high temperature this powder melts and forms a steel-gray crystalline mass, or, when heated with a little sulphur in the electric furnace, forms green octahedra. Ammonium sulphide and other alkaline sulphides precipitate hydrous manganese sulphide from a solution of a manganous salt, as a flesh-colored precipitate, which passes into green crystals when heated in the solution to 300° C. Manganese monosulphide forms double salts with the monosulphides of the alkalies, thus, $K_2S.3MnS$.

Manganous sulphate ($MnSO_4$) is prepared by strongly heating a mixture of manganese peroxide and sulphuric acid. From the calcined mass manganous sulphate is dissolved by water and precipitated on evaporation below 27° C. as $MnSO_4.5H_2O$, or as $MnSO_4.7H_2O$ below 8° C. Above 27° C. the monohydrate, $MnSO_4.H_2O$, is formed, but the last traces of water are removed from this only at 450° C. It decomposes and leaves a residue of Mn_3O_4 when heated to a bright-red heat. Manganous sulphate forms double salts with the sulphates of the alkalies as $K_2SO_4.MnSO_4.6H_2O$, and with aluminum sulphate as $MnSO_4.Al_2(SO_4)_3.24H_2O$ (manganese-aluminum pseudo-alum).

Manganous dithionate ($MnS_2O_6.3H_2O$ is obtained by passing sulphur dioxide through water in which finely divided manganese peroxide is suspended.

Manganese bisulphide (MnS_2) is found in nature as the reddish-brown mineral hauerite.

Manganic sulphate, $Mn_2(SO_4)_3$, is obtained, with the evolution of oxygen, as a green deliquescent powder by the action of sulphuric acid upon finely divided, precipitated peroxide at a temperature of 138° C. Manganic sulphate replaces aluminum sulphate in the alums, forming a series of manganese alums with the general formula $R'_2SO_4.Mn_2(SO_4)_3.24H_2O$, which crystallize in pink or red octahedra. The potassium and ammonium manganese alums are very unstable and have not been obtained pure, but the caesium and rubidium manganese alums have been prepared.

MANGANESE AND SELENIUM.

List of selenium compounds of manganese.

Manganese selenide	$MnSe$.
Manganese oxyselenide.	
Manganous selenite (hydrous)	$MnSeO_3:H_2O$
Manganese selenate.	
Hydrous manganese selenate	$MnSeO_4.2H_2O$ $MnSeO_4.5H_2O$
Manganic selenite	$Mn_2O_3.{}_4SeO_2$
Hydrous manganic selenite	$Mn_2O_3.3SeO_2.5H_2O$

DOUBLE SALT.

Manganese-potassium selenate (hydrous)	$MnK_2(SeO_4)_2.2H_2O$

MANGANESE AND NITROGEN.

List of nitrogen compounds of manganese.

Manganese nitrides	Mn_5N_2 Mn_3N_2
Basic manganese nitride	$Mn(OH)N_3$
Manganese nitrite.	
Manganous nitrate	$Mn(NO_3)_2$
Hydrous manganous nitrates	$Mn(NO_3)_2.6H_2O$ $Mn(NO_3)_2.3H_2O$
Basic manganous nitrate	$2MnO.N_2O_5.3H_2O$
Manganic nitrate.	

DOUBLE SALTS.

Manganese-cerium nitrate (hydrous)	$3Mn(NO_3)_2.Ce_2(NO_3)_6.16H_2O$
Manganese-thorium nitrate (hydrous)	$2Mn(NO_3)_2.Th_2(NO_3)_8.16H_2O$

Manganese nitrides (Mn_5N_2 and Mn_3N_2) are dark powders, the first being obtained when nitrogen, and the second when ammonia, is passed over finely divided manganese at a red heat. Both yield ammonia when heated with hydrogen, or when fused with potash.

Manganous nitrate, $Mn(NO_3)_2$, exists with $6H_2O$ and $3H_2O$. At 129.5° C. it decomposes with the formation of manganese oxides. Manganous nitrate is easily obtained by dissolving manganous carbonate in nitric acid.

MANGANESE AND PHOSPHORUS.

List of phosphorous compounds of manganese.

Manganese phosphides	Mn_5P_2 Mn_3P_2
Manganous hypophosphite	$Mn(PO_2H_2)_2.H_2O$
Manganous phosphite (hydrous)	$MnHPO_3.nH_2O$
Trimanganous orthophosphate	$Mn_3(PO_4)_2$
Dimanganous orthophosphate	$MnHPO_4$
Monomanganous orthophosphate (hydrous)	$Mn(PO_4H_2)_2.2H_2O$
Manganous pyrophosphate	$Mn_2P_2O_7$
Acid manganous pyrophosphate (hydrous)	$MnH_2P_2O_7.4H_2O$
Manganous metaphosphate (hydrous)	$Mn(PO_3)_2.nH_2O$
Manganic orthophosphate (hydrous)	$Mn_2(PO_4)_2.2H_2O$
Neutral manganic pyrophosphate (hydrous)	$Mn_4(P_2O_7)_5.nH_2O$
Acid manganic pyrophosphate	$MnHP_2O_7$
Manganic metaphosphate	$Mn(PO_3)_3$
Manganese apatite	$3Mn_3(PO_4)_2.Mn(FCl)_2$
Manganese wagnerite	$Mn_3(PO_4)_2.MnCl_2$
Manganese sulphophosphate	$Mn_3(PS_4)_2$

DOUBLE SALTS.

Manganese-potassium hypophosphate (hydrous)	$MnH_2P_2O_6.K_2H_2P_2O_6.3H_2O$
Manganese-potassium phosphates (anhydrous and hydrous)	$MnK_2P_2O_7$ $MnKPO_4$ $MnK_2P_2O_7.8H_2O$ $MnKP_2O_7$
Manganese-ammonium phosphates (anhydrous and hydrous	$MnNH_3PO_4.H_2O$ $Mn_2(NH_3)_2P_4O_{14}$
Manganese-sodium phosphates (anhydrous and hydrous	$MnNa_2P_2O_7.9H_2O$ $3Mn_2P_2O_7.2Na_4P_2O_7.24H_2O$ $MnNaPO_4$ $Mn_3Na_2(PO_3)_8$ $MnNa(PO_3)_3.3H_2O$ $MnNa(PO_3)_3$ $MnNa_3P_3O_{10}.12H_2O$
Manganese-sodium-ammonium phosphate (anhydrous and hydrous)	$Mn_2Na_2P_2O_7.10H_2O$ $Mn_2NaNH_3(PO_4)_2$
Manganese-lithium phosphate	$MnLiPO_4$

Two manganese phosphides, Mn_5P_2 and Mn_3P_2, are known. The phosphide Mn_5P_2 has been obtained by passing phosphorous vapor and hydrogen over manganous chloride. The phosphide Mn_3P_2 is prepared by heating manganese and red phosphorus in an atmosphere of hydrogen. Both are magnetic.

Manganous phosphates of several kinds have been prepared. The orthophosphate, $Mn_3(PO_4)_2.7H_2O$, is a white crystalline salt; the monohydrogen salt, $HMnPO_4.3H_2O$, forms rose-colored crystals soluble in water; and the dihydrogen salt, $H_4Mn(PO_4)_2.2H_2O$, forms deliquescent crystals which decompose on exposure to air into phosphoric acid and the monohydrogen salt. Ammonium phosphate precipitates from manganous salts manganous ammonium phosphate, $Mn(NH_4)PO_4.H_2O$.

Manganic metaphosphate, $Mn(PO_3)_3.H_2O$, orthophosphate, $MnPO_4.H_2O$, acid pyrophosphate, $MnHP_2O_7$, and other salts with phosphorus have been obtained. Manganic oxide and the dioxide, when dissolved in phosphoric acid, form a deep violet liquid from which a violet crystalline mass separates out. This decomposes with water, and manganic hydrate is precipitated from it by the alkalies. On evaporation of the red solution manganic metaphosphate is precipitated as a pink powder. Manganic orthophosphate is formed by the action of concentrated orthophosphoric acid on manganic acetate or simply by the addition of a concentrated solution of manganous nitrate little by little to dilute orthophosphoric acid heated to 100° C. It is a grayish-green crystalline powder, insoluble in water, but easily soluble in hydrochloric acid.

MANGANESE AND ARSENIC.

List of arsenic compounds of manganese.

Manganese arsenides	Mn_5As_4 $MnAs$ Mn_2As
Manganic arsenites (anhydrous and hydrous)	$3MnO.As_2O_3.5H_2O$ $3MnO.As_2O_3.3H_2O$ $3MnO.2As_2O_3$
Trimanganous arsenate (hydrous)	$Mn_3(AsO_4)_2H_2O$
Dimanganous arsenate (hydrous)	$MnHAsO_4.H_2O$
Monomanganous arsenate	$MnH_4(AsO_4)_2$
Manganous pyroarsenate	$Mn_2As_2O_7$
Basic manganese arsenate	$5MnO.2As_2O_5.5H_2O$
Manganic arsenate (hydrous)	$Mn_2(AsO_4)_2.2H_2O$

DOUBLE SALTS.

Manganese-potassium arsenate	$MnKAsO_4$
Manganese-ammonium arsenate.	
Manganese-sodium arsenates	$2MnO.4Na_2O.3As_2O_5$ $MnNa_4(AsO_4)_2$

Manganese arsenide, Mn_5As_4, occurs in nature as the mineral kaneite. The arsenide Mn_2As is magnetic and is obtained by heating the nonmagnetic arsenide MnAs.

Manganese arsenites are prepared by the action of alkaline arsenites on salts of manganese.

Manganous arsenates are formed by the action of arsenic acid on manganese carbonate.

MANGANESE AND ANTIMONY.

List of antimony compounds of manganese.

Manganese antimonide	$MnSb$
Manganese antimonates (hydrous)	$MnSb_2O_6.nH_2O$
Manganese sulphantimonate	Mn_3Sb_2S

DOUBLE SALT.

Manganese-potassium sulphantimonite	$MnKSbS_3$

Manganese antimonide is a black crystalline and strongly magnetic powder obtained by igniting a mixture of antimony and manganese thermite.

MANGANESE AND VANADIUM.

List of vanadium compounds of manganese.

Manganese vanadate	MnV_2O_6

DOUBLE SALT.

Manganese-potassium vanadate (hydrous)	$MnKV_5O_{14}.8H_2O$

MANGANESE AND BORON.

List of boron compounds of manganese.

Manganese monoboride	MnB
Manganese diboride	MnB_2
Manganese borates	$Mn_3B_2O_6$ MnB_4O_7
Manganese boracites	$6MnO.8B_2O_3.MnCl_2$ $6MnO.8B_2O_3.MnBr_2$ $6MnO.8B_2O_3.MnI_2$

Manganese monoboride (MnB) is a black crystalline magnetic powder prepared by the reduction of red oxide of manganese with boron, in a magnesia crucible, at a white heat.

Manganese diboride (MnB_2), in gray-black crystals which decompose in warm water, is obtained by igniting a mixture of manganese thermite and boron, or by heating a mixture of boric acid and manganese carbide.

Manganese borate (MnB_4O_7) is formed as a white powder when manganese sulphate is added to a solution of borax and the precipitate dried at 100° C.

MANGANESE AND CARBON.

List of carbon compounds of manganese.

Manganese carbides	MnC MnC_2
Manganese carbonate	$MnCO_3$
Basic manganese carbonate	$MnCO_3.6Mn(OH)_2.5H_2O$
Manganese cyanide	$Mn(CN)_2$

Manganese thiocyanates (anhydrous and hydrous)	$Mn(CNS)_2$ $Mn(CNS)_2.4H_2O$ $Mn(CNS)_2.3H_2O$ $Mn(CNS)_2.2H_2O$

DOUBLE SALTS.

Manganese-iron carbides	$Mn_3C.2Fe_3C$ $2Mn_3C.Fe_3C$ $4Mn_3C.Fe_3C$
Manganese-potassium carbonate (hydrous)	$MnK_2(CO_3)_2.4H_2O$
Manganese-cadmium carbonate.	
Carbonate of manganese and hydroxylamine (hydrous)	$4MnCO_3.3NH_2(OH).2H_2O$
Manganocyanide of potassium (hydrous)	$Mn(CN)_6K_4.3H_2O$
Manganocyanide of potassium and manganese	$Mn(CN)_6.MnK_2$
Manganocyanide of ammonium	$Mn(CN)_6.(NH_3)_4$
Manganocyanide of ammonium and manganese	$Mn(CN)_6.Mn(NH_3)_2$
Manganocyanide of sodium (hydrous)	$Mn(CN)_6Na_4.8H_2O$
Manganocyanide of sodium and manganese	$Mn(CN)_6.MnNa_2$
Manganocyanide of calcium	$Mn(CN)_6Ca_2$
Manganocyanide of strontium	$Mn(CN)_6Sr_2$
Manganocyanide of strontium and manganese	$Mn(CN)_6.MnSr$
Manganocyanide of barium	$Mn(CN)_6Ba_2$
Manganocyanide of barium and manganese	$Mn(CN)_6.MnBa$
Ferrocyanide of manganese (hydrous)	$Fe(CN)_6Mn_2.7H_2O$
Ferrocyanide of manganese and potassium or ammonium	$Fe(CN)_6MnR'_2$
Manganicyanide of potassium	$Mn(CN)_6K_3$
Manganicyanides of sodium (hydrous)	$Mn(CN)_6Na_3.4H_2O$ $Mn(CN)_6Na_3.2H_2O$
Manganicyanide of calcium	$Mn_2(CN)_{12}Ca_3$
Manganicyanide of barium	$Mn_2(CN)_{12}Ba_3$
Manganicyanide of iron	$Mn_2(CN)_{12}Fe_3$
Nitroprussiate of manganese.	

Manganese carbide (Mn_3C) is prepared by heating red oxide of manganese with charcoal or calcium carbide in the electric furnace. This is supposed to be the common form in which manganese occurs in the iron-manganese alloys. When strongly heated it dissociates, the manganese volatilizing, and the carbon remaining as graphite. When treated with water it yields hydrogen and marsh gas:

$$Mn_3C + 6H_2O = CH_4 + H_2 + 3Mn(OH)_2$$

It burns in oxygen and is readily attacked by fluorine and chlorine.

Manganese carbonate ($MnCO_3$) occurs in nature as rhodochrosite and as a constituent of manganocalcite, manganosiderite, and other carbonates. The hydrated carbonate is obtained as a white precipitate by mixing solutions of chloride or sulphate of manganese and sodium carbonate.

Manganese thiocyanate, $Mn(CNS)_2$, a yellow salt, is prepared from manganous sulphate and barium thiocyanate. With $3H_2O$ a hydrated green salt is formed.

Manganocyanide of potassium, $K_4Mn(CN)_6.3H_2O$, in dark-blue crystals, is obtained by the alteration of a green precipitate, $KCN.Mn(CN)_2$, formed when a concentrated solution of manganese acetate is warmed with solid potassium cyanide. It is also obtained in violet-blue crystals when manganous carbonate is heated to 40° or 50° C. in a solution of potassium cyanide.

Manganicyanide of potassium, $K_3Mn(CN)_6$, is obtained in dark-red crystals from the oxidation in air of a solution of potassium manganocyanide.

MANGANESE AND SILICON.

List of silicon compounds of manganese.

Manganese silicides	Mn_2Si $MnSi$ $MnSi_2$ Mn_3Si_2
Manganese fluorosilicate (hydrous)	$MnSiF_6.6H_2O$
Manganese silicates (anhydrous and hydrous)	$MnSiO_3$ Mn_2SiO_3 $Mn_3H_2(SiO_3)_4.H_2O$
Silicate and chloride of manganese	$2MnO.MnCl_2.SiO_2$

DOUBLE SALTS.

Manganese-iron silicides.
Silicates of manganese with magnesium, calcium, aluminum, and iron.

Four silicides of manganese have been described, Mn_2Si, $MnSi$, $MnSi_2$, and Mn_3Si_2. Mn_2Si forms in a steel-gray hard brittle mass when the two elements are heated together in the electric furnace, or when a mixture of silica, manganese oxide, and aluminum is fired. It is also prepared by heating a mixture of potassium silicofluoride, red oxide of manganese, copper, and sodium. It is decomposed by fluorine at ordinary temperatures, is attacked by steam, oxygen, and chlorine at a red heat, and dissolves in hydrochloric acid. Manganese monosilicide ($MnSi$) forms hard lustrous tetragonal crystals, and the disilicide ($MnSi_2$) forms dark-gray octahedra. Mn_3Si_2 is a new silicide which has recently been described by Gin.[a] It is obtained in prismatic crystals by the reduction of rhodonite in the electric furnace. It is attacked by hydrochloric and nitric acids.

Manganous silicate occur as isomorphous mixtures with silicates of iron, calcium, magnesium, aluminum, and many other metals, widely distributed through the earth's crust. Some have been prepared in the laboratory. Pure manganese silicates occur as rhodonite ($MnSiO_3$) and tephroite (Mn_2SiO_4).

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[a] Gin, C., Sur un nouveau siliciure de manganèse: Compt. Rend., vol. 143, p. 1229.

MANGANITES.

List of manganites.

Potassium manganites	$K_2O.16MnO_2.6H_2O$
	$K_2O.32MnO_2.10H_2O$
	$K_2O.7MnO_2$
	$K_2O.8MnO_2$
	$K_2O.10MnO_2$
	$K_2O.12MnO_2$
	$K_2O.2MnO_2$
	$K_2O.5MnO_2$
Sodium manganites	$Na_2O.8MnO_2.5H_2O$
	$Na_2O.12MnO_2.4H_2O$
	$Na_2O.16MnO_2.8H_2O$
Magnesium manganite	$2MgO.MnO_2$
Calcium manganites	$2CaO.MnO_2$
	$CaO.2MnO_2$
	$CaO.3MnO_2$
	$CaO.5MnO_2$
	$CaO.MnO_2$
Strontium manganites	$SrO.MnO_2$
	$SrO.2MnO_2$
	$SrO.5MnO_2$
	$2SrO.MnO_2$
Barium manganites	$BaO.2MnO_2$
	$BaO.MnO_2$
	$BaO.7MnO_2$
	$BaO.5MnO_2$
	$BaO.MnO_2.H_2O$
Zinc manganite	$ZnO.5MnO_2$
Manganese manganites	$MnO.10MnO_2$
	$MnO.5MnO_2.nH_2O$
	$MnO.4MnO_2$
	$MnO.3MnO_2$
	$MnO.2MnO_2$

Manganites are unstable compounds formed by the union of manganese dioxide with basic oxides of other metals. These are of various types, as $R'_2O.MnO_2$, $R'_2O.2MnO_2$, and $R'_2O.5MnO_2$, their composition depending on the amount of alkali present. Potassium manganite ($K_2O.5MnO_2$ or $K_2Mn_5.O_{11}$) is obtained as a yellow precipitate when carbon dioxide is passed into a potassium-manganate solution. Calcium manganite ($CaO.5MnO_2$ or $CaMn_5O_{11}$) is a black-brown precipitate prepared by pouring manganous nitrate into an excess of bleaching powder solution.

MANGANATES.

List of manganates.

Potassium manganate	K_2MnO_4
Sodium manganate	$Na_2MnO_4.nH_2O$
Calcium manganate.	
Strontium manganate	$SrMnO_4$
Barium manganate	$BaMnO_4.nH_2O$

The manganates ($R'_2O.MnO_3$ or R'_2MnO_4) are derived from the hypothetical acid H_2MnO_4 corresponding to the trioxide. They form green solutions which are stable only in the presence of free alkali. When diluted and warmed, or made slightly acid, they change to a pink, blue, or violet color, being converted to permanganates, and manganese dioxide is deposited:

$$3K_2MnO_4 + 2H_2O = 2KMnO_4 + MnO_2 + 4KOH.$$

Manganates may be obtained by the partial reduction of permanganates by such reducers as alcohol or sodium thiosulphate, or by the action of organic matter in the atmosphere.

Potassium manganate (K_2MnO_4) is formed by the fusion of potassium hydrate and manganese dioxide. In the absence of air the following reaction takes place:

$$3MnO_2 + 2KOH = K_2MnO_4 + Mn_2O_3 + H_2O.$$

In the presence of air or oxidizers more manganate is produced:

$$2KOH + MnO_2 + O = K_2MnO_4 + H_2O.$$

The fused mass is deep green and dissolves in water, forming a dark-green solution. The crystalline salt is deposited upon evaporation in a vacuum. Potassium manganate is also prepared by boiling a saturated potassium permanganate solution with a caustic potash solution.

Sodium manganate (Na_2MnO_4) is obtained by heating a mixture of sodium hydrate and manganese dioxide for sixteen hours. The mass formed is dissolved in a small quantity of water, from which the salt, $Na_2MnO_4.10H_2O$, crystallizes out. It is soluble in water, forming a green solution.

Barium manganate ($BaMnO_4$) is an emerald-green powder insoluble in water, but decomposed by acids. It is obtained when manganese dioxide is heated with baryta, or barium carbonate or nitrate, or when baryta water and barium permanganate are heated together.

PERMANGANATES.

List of permanganates.

Potassium permanganate	$KMnO_4$
Ammonium permanganate	NH_3MnO_4
Sodium permanganate	$NaMnO_4.3H_2O$
Lithium permanganate	$LiMnO_4.3H_2O$
Magnesium permanganate	$Mg(MnO_4)_2.6H_2O$
Calcium permanganate	$Ca(MnO_4)_2.5H_2O$
Strontium permanganate	$Sr(MnO_4)_2.4H_2O$
Barium permanganate	$Ba(MnO_4)_2$
Cadmium permanganate	$Cd(MnO_4)2.7H_2O$
Zinc permanganates	$Zn(MnO_4)_2.6H_2O$ $Zn(MnO_4)_2.4NH_3$
Aluminum permanganate.	

Cæsium permanganate	$CsMnO_4$
Rubidium permanganate	$RbMnO_4$
Silver permanganate	$AgMnO_4$
Cobalt permanganates	$(Co_2,12NH_3)(MnO_4)_6$ $(Co_2,12NH_3)Cl_4(MnO_4)_2$ $(Co_2,12NH_3)Br_4(MnO_4)_2$
Nickel permanganate	$16Ni(MnO_4)_2.4NH_3$

Permanganates ($R'_2O.Mn_2O_7$ or $R'MnO_4$) are salts of permanganic acid ($HMnO_4$).

Potassium permanganate ($KMnO_4$) is prepared by dissolving 10 parts of caustic potash in water and adding to this a mixture of 8 parts of manganese dioxide and 7 parts of potassium chlorate. On evaporating to dryness and heating the residue until the potassium chlorate is completely decomposed, a green mass is obtained. This is dissolved in boiling water, and the clear solution, on cooling, deposits black crystals of potassium permanganate, with greenish luster, which changes to steel-blue on exposure.

Potassium permanganate is also prepared from a solution of potassium manganate, by passing carbon dioxide through it:

$$3K_2MnO_4 + 2CO_2 = 2KMnO_4 + MnO_2 + 2K_2CO_3.$$

When this solution is evaporated, after filtering out the manganese dioxide, potassium permanganate is deposited. When boiled with strong caustic alkalies, the solution is reconverted to potassium manganate:

$$2KMnO_4 + 2KOH = 2K_2MnO_4 + H_2O + O.$$

Crystals of potassium permanganate yield a red powder and are soluble in water, forming a deep-purple solution. When they are heated to 240° C., they evolve oxygen and form potassium manganate and manganese dioxide. A mixture of potassium permanganate and sulphur or phosphorus explodes violently on percussion.

Sodium permanganate ($NaMnO_4$) is prepared like the potassium salt, but crystallizes with greater difficulty. Ammonium permanganate (NH_3MnO_4) is prepared by the decomposition of the potassium salt with ammonium chloride. Barium permanganate, $Ba(MnO_4)_2$, is obtained by the decomposition of the silver salt by barium chloride, or by passing carbon dioxide into water containing barium manganate in suspension. Silver permanganate ($AgMnO_4$) separates out on cooling from a warm solution of silver nitrate and potassium permanganate.

CHAPTER V.

USES OF MANGANESE.

HISTORY.

The use of manganese in the arts is of great antiquity, having been known at least as long ago as the time of the ancient Egyptians.[a] One of its first uses was in glass making. Egyptian and Roman glasswares have been shown by analyses to contain over 2 per cent of manganous oxide. Pliny mentions the use of manganese oxide under the name of "magnes" among the Romans for decolorizing glass. He considered it a variety of lodestone or magnetic iron ore.

The first experiments with oxide of manganese were made about 1656 by Glauber, but manganese oxide continued to be considered a variety of iron until late in the eighteenth century. In 1740 Pott showed that it formed a series of salts distinct from those of iron, but the existence of a metal in it was not known until the experiments of Scheele and Bergman in 1774. Even as late as 1758 Cronstedt speaks of it as a kind of earth with no metal except sometimes a small percentage of iron or a little tin. Scheele and Bergman were unable to isolate the metal (as Gahn did later), but their experiments showed that manganese oxide was a compound and not an element. Rinman, at about the same time, first called attention to the fact that manganese by degrees deprives iron of its magnetic qualities.

Up to the latter part of the eighteenth century the principal commercial use of manganese was in decolorizing glass and coloring both glass and pottery.

Chlorine was discovered by Scheele in 1774 in connection with his investigations on manganese compounds. About 1785[b] its use in the arts as a bleaching agent was introduced by Berthollet, and thenceforth manganese ores were consumed to a considerable extent in the manufacture of chlorine. This consumption, however, decreased materially after 1855, when successful processes came into use for the regeneration of the manganiferous waste product and its reconversion into manganese peroxide.

The use of manganese in steel manufacture started in 1839[c] from experiments by Heath for improving the malleable iron and cast steel derived from certain low-grade iron ores. He found that the addition of manganese produced a great improvement by making the product malleable and easily weldable. At first he added manganese in the form of manganese pig produced by smelting together the oxide and coal tar. Later he dispensed with the smelting and simply used dried bricks made of a mixture of manganese oxide and tar.

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[a] Penrose, R. A. F., Jr., Manganese: Its uses, ores, and deposits: Ann. Rept. Geol. Survey Arkansas for 1890, vol. 1, p. 3.

[b] Idem, p. 43.

[c] Idem, pp. 12 et seq.

The Bessemer process for making steel was announced in 1856 by Sir Henry Bessemer, but was not perfected until 1858. Soon after its invention it was found that owing to the extensive oxidation in the converter all the carbon was burned off and the metal reduced to wrought iron instead of steel. Robert Mushet invented a triple compound of iron, manganese, and carbon, essentially spiegeleisen, the addition of which, in a molten state, to the final product in the Bessemer converter introduced the requisite amount of carbon. The mixture was also found to counteract the effect of phosphorus and sulphur and to reduce small quantities of iron oxide formed. The part played by the manganese in these results was not understood until later. The extensive use of spiegeleisen and experiments for its perfection into high-grade ferromanganese began at that time.

Ferromanganese, containing 25 to 30 per cent manganese, was first produced for commercial use in 1865 by Henderson, followed closely by Prieger, who produced an alloy with 75 per cent manganese. The Terre Noir Company improved upon these earlier processes, and to them we owe the first production of rich and cheap ferromanganese.

The first successful experiments and tests of manganese steel were made by R. A. Hadfield, of Sheffield, England, about 1883.

METALLURGICAL USES.

FERROMANGANESE, SPIEGELEISEN, SILICOMANGANESE, AND SILICOSPIEGEL.

GENERAL DESCRIPTION.

Ferromanganese and spiegeleisen are alloys of manganese and iron, containing some carbon and usually some silicon. Alloys containing considerable quantities of silicon are silicospiegel and silicomanganese.

Spiegeleisen includes all iron-manganese alloys containing less than 20 per cent manganese; ferromanganese contains 20 to 80 or even 90 per cent manganese; an alloy containing more than 90 per cent is unstable under weathering conditions. Commercially, iron-manganese alloys containing up to 35 per cent manganese are frequently termed spiegeleisen, but texturally they are ferromanganese when they contain more than 20 per cent manganese. Carbon is present in varying amounts, depending somewhat on the amount of manganese, and ranging as high as 7 per cent in high-grade ferromanganese. In spiegeleisen or ferromanganese the percentage of silicon is rarely great, but in silicospiegel it may be as much as 15 per cent or more. If the iron is decreased and the silicon and manganese are increased, the alloy becomes silicomanganese. Spiegeleisen containing 20 per cent manganese should not have more than 1 per cent silicon, and ferromanganese with 80 per cent manganese not more than 1.6 per cent.[a] The greater the percentage of silicon present the less is the quantity of carbon. Small amounts of phosphorus and sulphur may be present. Of the former, however, there should not be more than 0.1 per cent in spiegeleisen containing 20 per cent manganese, nor more than 0.22 per cent in ferromanganese containing 80 per cent manganese.

The following table gives analyses of iron-manganese alloys, showing the variations in amounts of the different elements:

Analyses of iron-manganese alloys.[a]

	Mn.	Si.	Fe.[b]	Graphite.	Combined C.
Spiegeleisen	8.11	1.10	86.52	....	4.27
Do	19.74	.52	74.96	....	4.78
Ferromanganese	41.82	.42	52.13	....	5.63
Do	80.04	.97	12.46	....	6.53
Do	80.04	.14	12.62	....	7.20
Silicospiegel	23.90	4.90	67.66	....	3.56
Do	50.00	4.20	43.24	....	2.56
Do	19.64	10.74	67.44	0.33	1.85
Do	19.74	12.60	66.01	.67	.98
Do	24.36	15.94	58.50	.90	.30

[a] Hadfield, R. A., On alloys of iron and silicon: Jour. Iron and Steel Inst., 1889, No. 2, p. 226.
[b] Iron by difference. Phosphorus and sulphur are practically absent.

Spiegeleisen is used in steel manufacture when only small quantities of manganese are required. When larger quantities are necessary the addition of spiegeleisen would introduce an injuriously high amount of carbon; hence an alloy containing a higher percentage of manganese and proportionately lower percentage of carbon is required. Ferromanganese supplies this demand to some extent, but even it contains too much carbon for many purposes. Numerous experiments have been conducted recently and are being conducted for the preparation of carbon-free ferromanganese.

Phosphomanganese[b] is an iron-manganese alloy which has been used like ferrophosphorus in the manufacture of phosphorus steel. It has been produced with the following composition from manganese ore and apatite in the blast furnace:

Composition of phosphomanganese.

Mn	65
P	25
Fe	7
C	2
Si	1

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[a] Simmersbach, O., Berg- und Hüttenmännisches Rundschau, 1905, p. 305. Review, Jour. Iron and Steel Inst., 1905, No. 2, p. 680.

[b] Use of ferrophosphorus and phosphomanganese: Iron Trade Rev., Apr. 16, 1903, pp. 45-46; also Jour. Iron and Steel Inst., 1903, No. 2, p. 669 (Review).

MANUFACTURE.

Spiegeleisen is generally produced in ordinary blast furnaces from a manganiferous iron ore, or a mixture of manganese and iron ores in proportion to the percentages of manganese and iron desired in the alloy. With an increase in the percentage of manganese more heat is required for smelting, so that in early days ferromanganese could be produced in the blast furnaces only under great difficulties. With modern improvements, however, the reduction of the metal is facilitated, and at the present time ferromanganese may be produced in any properly arranged blast furnace with strong hot blasts. More recently ferromanganese is being produced on a small scale in electric furnaces.

The blast furnace is fed with coke, limestone, manganese ore, and iron ore, the last two being in the proportion that is desired for the metals in the pig. Manganese spar and roasted manganite ore are said[a] to be most suitable for the manufacture of iron-manganese alloys, but pyrolusite, psilomelane, and wad are most used. Hot air is blown through this mixture, entering through tuyères near the bottom of the furnace. The heat causes the decomposition of the coke and ores, producing the gases CO_2 and CO, which, on rising, heat the material in the upper part of the furnace. The melting occurs directly where the hot blasts enter the furnace. In the upper portion of the blast furnace the higher oxides are reduced by the heated gases to lower oxides, while in the lower portion the latter are reduced by CO to MnO, which in turn is reduced to metallic manganese by carbon.

Conditions for the production of iron-manganese alloys in the blast furnace are most favorable with good coke fuel, basic slag, slow reduction, and strong hot blasts. Coke is used for fuel because it admits of a sharper blast and gives greater heat. Charcoal, however, may be used. A basic slag is secured by using large charges of lime. This is important, because manganese unites too readily with an acid slag, and so is wasted. The fuel consumption is high, varying between 4,800 and 5,000 pounds[b] of coke per ton of the alloy, the higher-grade alloys requiring the most fuel. Hadfield in 1888 gave as a fuel consumption 38 to 44 hundredweight of coke per ton of metal, with ore containing between 40 and 50 per cent of manganese. A modern blast furnace produces about 34 to 36 tons of ferromanganese of 78 to 82 per cent manganese, in twenty-four hours. A very high temperature is required, and a blast of about 1,200° F. is used.[b] If a blast of higher temperature is used, say, about 1,400 or 1,500° F., silica is reduced and the furnace lining worn out. Even with moderate heat furnace linings have to be replaced frequently.

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[a] Simmersbach, O., Berg- und Hüttenmännisches Rundschau, 1905, p. 305.

[b] Weeks, J. D., Mineral Industries of the U. S.: Eleventh Census, 1890, pp. 285–329.

Considerable manganese is lost in the slag and fumes, though the loss has been greatly reduced in the last few years. According to Simmersbach[a] an alloy containing 40 per cent manganese should be produced with a slag containing about 7 per cent manganese, and an 80 per cent alloy with about 10 per cent in the slag. The following table shows the composition of the average ferromanganese slag of the present day:[b]

Average composition of ferromanganese slag.

Silica	28.21
Alumina	9.87
Lime	42.60
Calcium sulphide	3.42
Sulphur	1.60
Magnesia	1.72
Barium sulphate	2.07
Manganous oxide	10.97
Ferrous oxide	.15
Alkali	.89

The alloy obtained from the same furnace as this slag had the following composition:

Composition of alloy produced with slag of composition given above.

Manganese	80.47
Iron (by difference)	11.73
Carbon	6.79
Silicon	.69
Phosphorus	.21
Copper	.08
Arsenic	.03

When manganese spar is used in the furnace instead of the oxide, the resulting slag is higher in manganese.

The preparation of ferromanganese in the electric furnace is accomplished by mixing manganese and iron oxides with powdered carbon and suitable slagging materials and heating the mixture in a furnace of the resistance type until the reduction is complete.[c] The metallurgical side of the process is similar to others in which carbon is the reducing material, but electric heating gives a higher temperature.

The furnaces are generally designed for resistance heating, but combined arc and resistance heating is employed in the earlier stages of the operation. The simplest form of the furnace is merely a column with square cross section lined with suitable refractory material and provided with two massive carbon electrodes, a fixed one at the base and a movable one in the shaft of the furnace. As a lining the oxide of the metal to be reduced is generally employed, as this contains only elements already present in the charge. The charge, consisting of a mixture of ore, coke, and slagging materials, all in a finely divided state, is fed to the furnace from above, and the molten metal or alloy is tapped periodically at the foot of the shaft.

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[a] Simmersbach, O., loc. cit.

[b] Roberts, Edwin G. Ll., and Wraight, Ernest A., The preparation of carbon-free ferromanganese: Jour. Iron and Steel Inst., 1906, No. 2, p. 237.

[c] Kershaw, J. B. C., The manufacture and use of ferro alloys: Iron Trade Rev., July 16, 1908.

The aluminum reduction process is also employed in the manufacture of ferro alloys, more especially the alloys of iron with silicon, tungsten, vanadium, chromium, and molybdenum.

CONSTITUTION.

The exact nature of the iron alloys of manganese is not known, but the metals are supposed to be partly in the form of carbide and partly in solid solution. The common carbides of iron and manganese are Fe_3C and Mn_3C, but many analyses of ferromanganese show carbon present in amounts greater or less than that required by mixtures of these carbides. The excess amounts are not present as free carbon (graphite); hence either there are other carbides present that are not known or the excess carbon is in solid solution in the carbides present. The quantity of carbon absorbed by a manganese-iron alloy is dependent (1) on the percentage of manganese present, as there is a great affinity between carbon and manganese; (2) on the temperature of fusion and other furnace conditions, and (3) on the presence of carbides besides Mn_3C and Fe_3C. With an increase in the proportion of manganese in alloys, a marked change in the capacity to dissolve carbon occurs at about 20 per cent of manganese, and this percentage also governs the change from the platelike crystalline structure of spiegeleisen to the granular crystalline structure of ferromanganese. A similar change occurs at about 70 per cent of manganese. The amount of silicon present depends on the quantity of silica in the ore and flux fed to the furnace.

Ferromanganese and spiegeleisen are white or light-gray with bright metallic luster. Spiegeleisen has a brilliant platelike crystalline structure, whence it takes its name "mirror iron." When it contains less than 4 per cent of manganese it assumes a fibrous or columnar structure. Ferromanganese[a] has a granular compact matrix, in which two main types of crystalline forms occur. The less common of the crystal types is platelike and similar to the crystalline structure of spiegeleisen; the other type is prismatic. There is no regularity in the formation of these crystals; both may form in the same mass, or different masses may have different crystalline forms. The two types of crystals taken from the same alloy mass have been analyzed and show practically no difference in composition; neither do they show a marked difference in composition from the matrix.

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[a] Roberts, Edwin G. Ll., and Wraight, Ernest A., op. cit., p. 243.

The same crystalline forms are present in low and high grade ferromanganese; hence their structure does not change with the composition of the alloy.

The following analyses show the composition of the matrices of two specimens of ferromanganese, one containing prismatic and the other platelike crystals, and of prismatic crystals from one of these:

Composition of ferromanganese groundmass and prismatic crystals.

	Groundmass of specimen with prismatic crystals.	Groundmass of specimen with platelike crystals.	Prismatic crystals.
Mn	80.00	79.20	83.60
Fe	12.60	13.60	8.80
Si	.61	.75	.56
C	6.65	6.06	6.81

The first specimen was produced by slowly cooling a large mass of the molten alloy, and the second by rapidly cooling a smaller quantity from a temperature far above the melting point by pouring it into a cold steel mold. The prismatic crystals correspond closely in composition with the double carbide $Fe_3C.10Mn_3C$.

The following analyses show the composition of the two types of crystals from the same mass, prepared by slowly cooling it for twenty hours:

	Prismatic crystals.	Platelike crystals.
Mn	80.88	79.76
Fe	10.52	11.38
Si	1.12	1.70
C (combined)	7.28	6.76
Graphite	None.	Trace.

Carnot and Goutal[a] have separated carbides from various grades of iron-manganese alloys, and have deduced the following:

Double carbide $Fe_3C.4Mn_3C$ exists in ferromanganese having 85–74 per cent manganese.

Double carbide $Fe_3C.2Mn_3C$ exists in ferromanganese having 74–60 per cent manganese.

Double carbide $2Fe_3C.Mn_3C$ exists in ferromanganese having 60–30 per cent manganese.

Double carbide $4Fe_3C.Mn_3C$ exists in ferromanganese having below 18 per cent manganese.

The last double carbide is supposed to be that present in spiegeleisen.

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[a] Annales des mines, vol. 18, 1900, p. 263.

According to Moissan, however, no definite double carbide of iron and manganese exists, and the two carbides Fe_3C and Mn_3C are able to replace each other in the mixed carbide $(Fe,Mn)_3C$.

The following general statements[a] may be made with regard to the constitution of iron-manganese alloys: Ferromanganese consists of manganese and iron in which—

1. Carbon may be present in such an amount as to form some carbide of iron and manganese, leaving either free manganese or iron in which these carbides are dissolved.
2. Carbon may be present in such a degree that the alloy consists entirely of a mixture of double carbides of iron and manganese, mechanically or chemically combined.
3. The carbon may be present in excess to satisfy such carbides, the remainder of the carbon being dissolved in them.

It has been found that a single mass of ferromanganese is not homogeneous with regard to composition. Samples have been taken from different parts of the same mass for analysis and found to vary over 2 per cent in metallic manganese content. It has been found also that the crystals contain a slightly higher percentage of manganese than the matrix.

USES IN STEEL MANUFACTURE.

Spiegeleisen and ferromanganese are used in the manufacture of steel in the following ways: (*a*) As reducers of iron oxide formed in the final melting, the manganese oxide formed going into the slag; (*b*) As recarbonizers of steel, the alloys being used for their carbon as well as their manganese content; (*c*) for counteracting phosphorus and sulphur by the formation of manganese phosphide and sulphide; and (*d*) in the manufacture of manganese steel, used for railroad and street-car rails on curves, for burglar-proof safes, dredger pins, car wheels, shoes and crusher plates in gold mills, and for other purposes. The addition of small amounts of manganese gives to steel hardness, ductility, and strength.

(*a*) During the final melting the molten iron in the converter absorbs small quantities of oxygen from the blast, forming iron oxide, the presence of which makes the steel difficult to forge. When a small amount of manganese is added it absorbs the oxygen from the oxide of iron, forming manganese oxide, which combines with the slag to form a protosilicate. Small particles of slag that are disseminated through the molten metal also contain small quantities of oxygen. Though the presence of oxygen in this form is less objectionable, the removal of the slag particles is very desirable, and is largely accomplished by manganese. The manganese unites with the silicate of iron composing the slag particles and forms a double silicate of iron and manganese, the presence of which causes the coalescence of the slag particles from their disseminated condition. They rise and join the main body of the slag at the surface. It is not all removed, however, and even the best steels contain small particles of manganese silicate. Some of the manganese combines directly with the slag, some is volatilized, and some combines with other impurities, so it is difficult to determine what quantities of the ferromanganese or spiegeleisen should be added in each case to produce the desired result.

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[a] Roberts, E. G. Ll., and Wraight, E. A., op. cit., p. 248.

(*b*) On account of the extensive oxidation in the Bessemer converter, all or nearly all of the carbon is oxidized, leaving the metal in the form of wrought iron instead of steel. To remedy this, ferromanganese or spiegeleisen, either solid or molten, is added during the final melting to restore the requisite amount of carbon and prevent further oxidation.

(*c*) Manganese neutralizes the effect of sulphur by forming a manganese sulphide, which probably goes partly into the slag and partly remains in the steel. All good steels contain sulphur in this form. It counteracts the effect of phosphorus by forming the phosphide, Mn_3P_2. Manganese tends to keep carbon from separating out as graphite, and to increase the power of carbon to combine with iron.

(*d*) Ferromanganese is used in the manufacture of manganese steel, the nature and uses of which are described in the next section.

HADFIELD'S MANGANESE STEEL.[a]

FIRST EXPERIMENTS.

Experiments with manganese steel were first carried on by the Terre Noir Company about 1878, while they were perfecting the manufacture of commercial ferromanganese. The use of manganese was limited to 2½ per cent, however, on account of the brittleness of the product when more than this percentage was used.

About 1883 experiments on manganese steel were begun by R. A. Hadfield, at the Hecla Works, Sheffield, England. He discovered that though the product containing between 2½ and 6 per cent manganese was extremely brittle a return in strength occurred after 7 per cent was passed, and that as the percentage of manganese increased to 14 or 15 a very strong and hard alloy was obtained. He found that above this percentage there was a decrease in toughness, though not in transverse strength, which continued up to 20 per cent, after which a rapid decrease took place. These facts apply to both the cast and the forged alloys, but more especially to the latter. The decrease in strength that accompanies an increase of manganese to more than 14 or 15 per cent is partly due to the resulting increase in the carbon to 1½ to 2 per cent.

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[a] Hadfield, R. A., Iron alloys, with special reference to manganese steel: Trans. Am. Inst. Min. Eng., vol. 23, 1893, p. 148; On manganese steel: Jour. Iron and Steel Inst., 1888, No. 2, p. 41; Manganese and its application to metallurgy: Minutes Proc. Inst. Civ. Eng., vol. 93, 1887-1888, pt. 3, p. 1; Some newly discovered properties of iron and manganese: Idem, p. 61.

PHYSICAL PROPERTIES.

Manganese steel, in its most serviceable form, contains about 13 or 14 per cent manganese. This alloy possesses a combination of hardness, tenacity, and ductility which makes it valuable for many purposes. Its use, however, has been limited somewhat by its extreme hardness, on account of which it is almost impossible to work it with machine tools. The material, therefore, has to be cast in very nearly the form in which it is intended to be used.

Manganese steel is not so liable to honeycombs as ordinary steel, and the addition of silicon is unnecessary. It is very fluid and can be run into thin sections but cools more rapidly than ordinary steel and has a greater contraction. It is manufactured by any of the ordinary steel-making processes; the basis (the material before the ferromanganese is added) is preferably decarbonized iron or mild steel. The ferromanganese is added in a molten state, or very highly heated. It is important that carbon should be kept as low as possible, especially in the 14 per cent material, in which it should not exceed about 1 per cent, as the product would be inferior. For this reason the ferromanganese used should contain a high percentage of manganese—that is, 80 to 84 per cent. To obtain 14 per cent manganese steel, 14½ per cent of manganese must be added, as one-half per cent is oxidized in reducing the iron oxide.

Ordinary steel, whether cast or forged, may contain as much as 1½ per cent manganese without showing any marked difference in quality, provided the carbon percentage is low. But with higher percentages there is a decrease in strength and ductility, which is accentuated to a remarkable degree between 3½ and 5 per cent.

Cast manganese steel containing from 2½ to 6 per cent manganese is extremely brittle and can be chipped with a small hammer and ground to a powder. When hot, however, it is extremely ductile and may be drawn down to any desired sizes. It is worthy of note that the amount of carbon in this brittle material is very small, little more than that in mild steel. The remarkable weakness of the cast product is no doubt intensified by a peculiar crystallization which resembles that of "scalded" crucible steel. The brittleness is not so marked if the metal is poured at lower temperature, but steel with 3½ to 6½ per cent manganese in whatever shape or under whatever conditions it is cast is always deficient in strength compared with ordinary steel. With the increase of manganese beyond about 6½ per cent a remarkable change occurs, the exact point being somewhat influenced by the casting temperature and other considerations. By this change the brittleness gradually disappears and toughness and ductility return. The alloy also loses its magnetism, and at 13 per cent is practically nonmagnetic. At about 14 per cent the maximum of strength is obtained; the cause of the succeeding decrease is complicated by the higher carbon content. It is possible that if the carbon content could be kept low steel containing 25 or 30 per cent of manganese might have considerable strength.

The toughness and resistance to fracture of manganese steel containing between 8 and 20 per cent of manganese is not altogether produced immediately upon casting; further treatment, such as "water toughening," gives the best results. The material as cast is often remarkably tenacious and ductile, notwithstanding its great hardness, but this property is to some extent uncertain without further treatment. The uncertainty is probably due to variation in the casting temperature and other similar causes.

"Water toughening" consists in heating the article to 1,800° or 2,000° F. and then plunging it in cold water. The nearer this temperature is approached and the colder the water the harder will be the metal. Such treatment would cause water cracking, brittleness, and other defects in ordinary steel.

Forged manganese steel containing between 2½ and 6 per cent manganese is very much stronger than the same material when cast, but is still very brittle as compared with ordinary steel. It is most brittle with about 5 per cent. Heating or water quenching does not seem to modify this character to any extent.

The peculiar crystallization of the cast material disappears after hammering and the grain is then coarse and open. If it is reheated and cooled quickly in the open air a fine close grain is obtained.

With 10 per cent manganese the water-toughened forged manganese steel possesses about as much ductility as mild steel, but much higher tenacity. With increase past 13 per cent there is a considerable increase both of ductility and tenacity; the maximum is reached at 14 per cent, as it is in the cast product. With increase above 14 per cent, there is a decrease in strength, also complicated by the presence of carbon, and at 22 per cent the malleability is lost. With the forged product, as with the cast product, there is no object in manufacturing a material containing more than 14 per cent manganese, the best results being obtained with the 10 to 14 per cent material.

Water quenching is also of great importance in producing strength and tenacity in the forged manganese steel.

Experiments have been attempted to note the effect of plunging manganese steel in sulphuric acid and in oil. The acid was found to be more satisfactory than the oil, but neither was found to be preferable to water. A beneficial effect is also produced by reheating and cooling in air. This increases both the tenacity and the ductility.

The physical properties of manganese steel depend largely upon the microstructure, as is true of all other alloy steels. The microstructure is largely dependent on the sum of the quantities of carbon and manganese (C+Mn) present. The following table shows the microstructures which develop in manganese steel with varying percentage of carbon and manganese:

Constitution of manganese steel.[a]

Microstructure.	Percentage of manganese with—	
	Carbon 0.2 per cent.	Carbon 0.8 per cent.
Perlite	0–5	0–3
Martensite and troostite	5–12	3–7
γ iron	12+	7+

[a] Guillet, L., Quaternary steels: Jour. Iron and Steel Inst., 1906, No. 2, p. 6.

The manganese steels containing γ iron are the most desirable for commercial use because of their hardness and tenacity. Martensitic steels though hard are generally very brittle.

On account of their great hardness, it is scarcely possible to machine manganese steels on a practical scale. The cast material, with about 5 or 6 per cent of manganese, is hardest, and no tool will face or touch it. With increase of manganese there is a decrease in hardness up to 10 per cent, at which percentage it is in its softest condition. After this point is passed the hardness again increases, until at 22 per cent of manganese another hard stage is reached, but not as hard as the 5 per cent stage. The cause of the great hardness of manganese steel is not known. Manganese when added to copper has no similar effect. It is thought possible that iron has the property of changing its form, when combined with manganese, in a way not yet understood.

Manganese steel, although it has a large iron content, has the property of being almost entirely nonmagnetic, not being attracted by the strongest magnets. An alloy with 87 per cent iron, 12 per cent manganese, and 1 per cent carbon has a permeability between 1.3 and 1.5.[a] It retains no residual magnetism even after strong magnetizing forces have been applied. It is believed that the alloy is not a mechanical mixture, but that the manganese and iron combine to form a molecule with properties different from either.[b] It has been found that when manganese steel drillings of 20, 30, and 36 per cent manganese were heated to redness and then cooled, they became magnetic. That this was not due to the oxidation of the manganese was shown by the fact that the material had the same weight before and after heating, and that it acquired the same magnetic property when cooled in hydrogen.

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[a] Ewing, J. A., Magnetic induction of iron and other metals.

[b] A new use for manganese steel: Min. World, June 6, 1908.

USES.

Manganese steel is used for many purposes, although its application is considerably restricted because of the difficulty of machining it. In a large number of articles for which it is used this difficulty is surmounted by so arranging the castings or forgings that they can be used without any tooling. The greater first cost is compensated by the saving of the cost of machining. Manganese steel has a considerable advantage in being almost free from blow holes or honeycombs, and in possessing greater fluidity than cast steel.

Manganese steel is used for dredger pins and other parts of dredging machines; for dipper teeth of steam shovels; for parts of crushing and grinding machinery, such as shoes and crusher plates in ore mills; for ore chutes and screens; for elevator links, especially where the wear and tear is heavy; for agricultural implements, as plow shares and plow points, cultivator fingers, and even shovels, spades, rakes, hoes, and forks; for wheels, tires, and axles on railway cars, street cars, and mining wagons; for cogwheels; for couplers between railway cars; for railroad and street-car rails on curves; for burglar-proof safes; and for many other purposes. One of its most important uses at the present time, on account of its nonmagnetic property and hardness, is for cover plates and coil shields in large electromagnets,[a] such as are used for clutches in lifting pig and scrap iron at foundries.

QUATERNARY MANGANESE STEELS.[b]

A quaternary steel is distinguished from a ternary steel by the fact that it contains two elements besides carbon and iron, while a ternary steel contains but one. Thus manganese steel, chromium steel, nickel steel, and tungsten steel are ternary steels, while manganese-nickel and chromium-tungsten steel are quaternary steels. The principal manganese quaternary steels are manganese-nickel steel, manganese-chromium steel, and manganese-silicon steel.

The microstructures of these steels consist in general of a superposition of the microstructures of the constituent ternary steels, modified by the total quantity of hardening elements present, that is, the sum of the elements besides iron. For instance, if chromium is added to manganese steel it has the same effect as the addition of more manganese would have, and superimposed upon this effect would be a tendency toward developing a new and distinct microstructure characteristic of chromium steel—that is, carbide microstructure.

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[a] Hopkinson, Magnetism of iron: Philos. Trans. Roy. Soc. London, 1786–1885, p. 445.

[b] Guillet, L., Quaternary steels: Jour. Iron and Steel Inst., 1906, No. 2, pp. 1-141.

Nickel-manganese steels are either perlitic, martensitic, or contain γ iron, according to the quantity of "carbon + manganese + nickel" present. As the structures of nickel steel and manganese steel are very similar the addition of one to the other produces no new structures. Nickel-manganese steels are capable of being substituted for nickel steels for many purposes and possess the advantage of a smaller cost.

Manganese-silicon steels are either perlitic or contain γ iron. The addition of silicon to manganese steel weakens its mechanical properties in the normal state, but confers the advantage of greater tenacity upon quenched steels, provided both manganese and silicon are present in small quantities. The high-class spring steels consist of manganese-silicon steel in which neither manganese nor silicon is present in excess of 1 per cent.

Manganese-chromium steels consist of the following microstructures: Perlite, martensite with or without carbide, and γ iron with or without carbide. Apparently the addition of chromium to manganese steel has no other effect on the structure than the addition of manganese would have, except that if the percentage is sufficiently high a double carbide of chromium and manganese is formed, especially if the carbide also is increased. Manganese-chromium steels possess great hardness and resistance to shock, and might be substituted for nickel-chromium steels. In fact, manganese might be substituted for nickel in many of the quaternary nickel steels, thus lowering the cost.

ALLOYS WITH OTHER METALS THAN IRON.[a]

Manganese forms alloys with copper, zinc, tin, aluminum, lead, magnesium, and other metals.

CUPROMANGANESE.

The most important of the manganese alloys, with the exception of the iron alloys, is cupromanganese, an alloy with copper. This is used in the manufacture of manganese bronze, manganese brass, and manganese German silver.

Cupromanganese may be prepared by heating to a white heat for several hours, in a graphite crucible, a mixture of powdered manganese ore, coal dust, and granulated copper, with a cover of fluorspar, common salt, and charcoal dust. At the proper time the liquid alloy may be poured out and when cooled is a hard, tough, whitish-gray material.

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[a] References on alloys other than iron:

Brannt, Wm. T., The metallic alloys, 1896, p. 312.

Thurston, R. H., Materials of engineering, pt. 3.

McTaggart, H. A., On the constitution and properties of Heusler's alloys: Univ. Toronto Studies; Papers from physical laboratories, No. 23, 1908.

Elect. Eng., London, vol. 3, p. 704.

Another method of preparing it is to melt in a reverberating furnace with regenerative firing a mixture of cupric oxide, coal, and manganic oxide, the last obtained as a by-product in the manufacture of chlorine. The result is a malleable, ductile alloy, with from 5 to 30 per cent of manganese.

Cupromanganese has also been prepared by mixing metallic manganese and copper, or ferromanganese and copper, the latter mixture producing a ferriferous alloy. When the alloy contains but a small percentage of manganese, about 4 per cent or less, it has a copper-red color. With 10 to 15 per cent manganese it is yellowish-gray, and with a larger percentage it becomes gray, 18½ per cent having as much bleaching effect as 25 per cent of nickel. An alloy with 8 per cent manganese is ductile and malleable, but one with 12 to 15 per cent is brittle.

Cupromanganese is added in small quantities to copper or its alloys to withdraw the oxygen and thus give them greater density and strength. By the addition of larger amounts greater hardness is imparted.

MANGANESE BRONZE.

Manganese bronze is prepared by adding small pieces of cupromanganese to ordinary bronze, melted in a crucible under cover of charcoal with possibly some potash and soda. The whole is melted and the mixture is stirred together with a retort graphite rod. Or, copper and cupromanganese may be melted together in a crucible under a cover of coal dust and then the requisite quantity of tin added, with thorough stirring. Frequently the alloy is produced by adding ferromanganese or spiegeleisen to bronze; such an alloy contains a small quantity of iron.

Tough, malleable manganese bronze of a brass-yellow color contains essentially 75 to 76 per cent copper, 16 to 17 per cent manganese, and 5 to 6 per cent tin. An addition of aluminum up to 5 per cent increases the strength and elasticity and gives it a silver-white appearance. Zinc is often added up to 5 per cent, and lead is sometimes added in small quantities.

Another common proportion[a] in manganese bronze is copper 88 per cent, tin 10 per cent, and manganese 2 per cent. This is a ductile, hard, and tenacious alloy of a reddish-white color. With 10 per cent manganese the color is white with a reddish tinge, with 20 per cent manganese it is a silver white, and with 40 per cent manganese it is an iron gray. When rich in copper the alloy has a decided rose hue.

Early experiments with this alloy were unsatisfactory, and led to the conclusion that it was useless on account of its ready oxidation at high temperature. More recent experiments have shown a small quantity of manganese, advisably about two-thirds of 1 per cent, to be very serviceable. It frees the alloy from oxides and makes it homogeneous, thus producing greater strength and resistance to wear, being especially adapted for bearings.

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[a] Thurston, R. H., Materials of engineering, pt. 3.

When forged, manganese bronze acquires remarkable strength and toughness. During this process the alloy should not be heated to a higher temperature than cherry-red and should not be worked at a black heat. Thus strengthened, manganese bronze is used for screws, nails, wire, pins, bolts and nuts, pump rods, rudders, and steamboat propellers. Articles manufactured from manganese bronze are used especially in the construction of ships.

MANGANESE BRASS.

Manganese brass is a silver-like alloy with about 10 parts copper, 30 parts manganese, and 20 to 30 parts zinc, which can be forged and rolled at a red heat. Where not required to stand high temperatures, it contains 49 parts copper, 21 parts manganese, and 5 to 10 parts zinc. It is used for soldering with the following composition: Copper, 7; manganese, 3; silver, 1 to 2. For coins, an alloy with 65 per cent copper, 25 per cent manganese, and 10 per cent zinc may be used. From 5 to 10 per cent nickel may be substituted for part of the manganese.

MANGANESE GERMAN SILVER.

An alloy containing copper 60, zinc 15, and ferromanganese (with 70 to 80 per cent manganese) 40 is used as a substitute for German silver. It is also known as silver bronze. For bearings, cocks, and valves this alloy is used with the following composition: Copper 60, zinc 10, and ferromanganese (containing 60 per cent manganese) 40. Nickel is frequently added and also small quantities of aluminum and silicon. The addition of 1¼ per cent of aluminum gives to the alloy good casting qualities and noncorrodibility.

MANGANESE AMALGAM.

Manganese amalgam is a manganese-mercury alloy with the composition Hg_5Mn_2. It is prepared by electrolyzing a saturated solution of manganese chloride, mercury being used as the negative pole. A pasty mass is obtained, which, when compressed, yields a slate-colored mass with a specific gravity of 12.8.

MANGANESE-ALUMINUM ALLOYS.

Manganese-aluminum alloys with crystalline forms and definite chemical composition have been produced[a] by direct fusion of the metals, by the fusion of manganese salts with aluminum, or by the reduction of manganese oxides with aluminum. Alloys of the following compositions have been prepared: $MnAl_3$, Mn_2Al_7, $MnAl_4$, $MnAl_6$, $MnAl_2$, and Mn_2Al_3. These may be comparable to manganese carbides and silicides (pp. 237, 238, 239). Some manganese-aluminum alloys are hard enough to scratch glass.

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[a] Moissan, Henri, Traité de chimie minérale; IV, Métaux, p. 589.

Both manganese and aluminum when alloyed with iron destroy its magnetic properties. Triple alloys of manganese, aluminum, and iron, however, of the following composition, are reported by Hogg[a] as strongly magnetic.

Analyses of magnetic alloys of manganese, aluminum, and iron.

	1.	2.
Fe	10.80	14.80
Mn	54.86	75.40
C	2.32	5.55
Al	25.34	3.06
Si	.79	.80
S	Trace.	Trace.
P	.11	.18
Cu	.07	.08

The alloy shown by analysis 1 was found to disintegrate on exposure; the other was stable.

HEUSLER'S ALLOYS.[b]

Much attention is being directed at the present time to certain magnetic alloys of copper, manganese, and aluminum, known as Heusler's alloys. They were discovered some years ago and numerous experiments have been conducted to ascertain the cause of their peculiar magnetic properties. It has been found that the permeability increases with the addition of manganese until aluminum and manganese are present in the ratio of their atomic weights (Al 27.11 and Mn 55.00). When the percentage of manganese is increased beyond this the magnetization decreases. The maximum magnetization attained up to the present is about one-third of that of the best iron. Copper apparently serves no other purpose than to make the alloy—otherwise hard and brittle—soft enough to be cast and handled.

It was found by Asteroth that heating the alloy to a high temperature and quenching it eliminated hysteresis, but that when it was reheated above the temperature of transformation, cooled for three hours, and aged at a temperature of 140° C. the hysteresis returned. It seems probable that the magnetism depends on the molecular arrangement and that quenching prevents the magnetic molecules from settling into positions in which they can obey magnetizing forces. Crystallization facilitates such a molecular arrangement.

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[a] Hogg, T. W., Notes on some alloys of iron, aluminum, and manganese: Chem. News, vol. 46, p. 140.

[b] McTaggart, H. A., op. cit.; also Elect. Eng., loc. cit.

Recent experiments on the microstructure of the alloys, conducted in the physical laboratory of the University of Toronto, by H. A. McTaggart, served to emphasize their crystalline texture. Alloys of different composition were etched and examined under the microscope, and it was found that those having the highest magnetization had a pronounced and peculiar crystalline structure. The following table shows the composition of some of the alloys used:

Analyses of Heusler's alloys.

	1.	2.	3.	4.
Al	8.00	9.70	14.30	15.90
Mn	32.10	25.60	28.60	23.90
Cu	59.80	64.60	57.10	60.30

Though all exhibited considerable magnetism, it was found that the alloy of the composition shown by analysis 3 was the most magnetic. Under the microscope this alloy was found to consist of large, distinct, regular crystals through which were scattered smaller fern-shaped crystals of what appeared to be manganese. The alloy shown by analysis 2 also exhibited a crystalline structure, but the crystals were irregular and were interlocked with each other; the alloy shown under analysis 1 exhibited no definite crystalline structure. Neither alloy had the fernlike crystals of manganese. The alloy shown under analysis 4 had distinct regular crystals, but the fernlike forms had changed to rosettes or star-shaped masses. The experimenter therefore concludes that the magnetic properties of these alloys accompany the fern-shaped crystals. Experiments have not been conducted to show the effect of heat and quenching on the crystalline forms, nor have the different crystal forms been analyzed to show their composition.

OTHER ALLOYS.

Various combinations in various proportions of copper, zinc, tin, magnesium, and to some extent iron with manganese have been experimented on and alloys with different properties produced. Alloys of manganese with aluminum, tin, antimony, arsenic, bismuth, and boron are receiving attention on account of their peculiar magnetic properties.

COPPER, LEAD, AND SILVER REDUCTION.

Manganese oxides are used as substitutes for iron oxide for flux in the reduction of copper and silver ores. Many such ores themselves contain considerable iron and manganese oxides, so that a less amount of flux has to be added in the smelters. Any metals, such as silver and lead, that may be contained in the flux are recovered during the smelting. The iron and manganese go into the slag and become waste products.

CHEMICAL USES.[a]

USES AS AN OXIDIZER.

GENERAL STATEMENT.

The peroxide of manganese (MnO_2), occurring in nature as the minerals polianite, pyrolusite, and psilomelane, is the only oxide of this metal that can be used for oxidizing purposes. It can be so used because one of its oxygen atoms is loosely combined and may be liberated by heat or with acids. This part is known as its "available oxygen." MnO_2 theoretically contains 63.2 per cent metallic manganese and 36.8 per cent oxygen, and as half of the latter may be liberated the available oxygen amounts to 18.4 per cent. Practically, however, 13 to 17 per cent of oxygen only is available, on account of impurities in the peroxide. Both the manufactured peroxide of manganese and the native minerals, especially pyrolusite, are used for oxidizing purposes, but the latter must be very pure. Manganates and permanganates are also used as oxidizers. Braunite and manganite are not used, because they are lower oxides (Mn_2O_3) and have no available oxygen, though their manganese content is higher than that of the peroxide. For oxidizing purposes, therefore, the manganese itself is not used, but acts only as a carrier of oxygen, and is valuable because of the facility with which it unites with a large amount of oxygen and the equal facility with which it yields part of this oxygen upon treatment with acid or heat.

MANUFACTURE OF CHLORINE.

In the manufacture of chlorine manganese peroxide is used as an oxidizer in producing a more powerful oxidizer. The process is accomplished through the action of the available oxygen in the peroxide upon a compound of chlorine, breaking it up and setting free the chlorine. This is accomplished either with HCl or with NaCl in the presence of H_2SO_4, as shown in the reactions below:

$$MnO_2 + 4HCl = 2H_2O + MnCl_2 + Cl_2.$$
$$2NaCl + MnO_2 + 2H_2SO_4 = Na_2SO_4 + MnSO_4 + 2H_2O + Cl_2.$$

It will be noticed that in the second of these equations all the chlorine is set free, but in the first part of it remains in combination with the manganese. In early times, when hydrochloric acid was very expensive, the second method was generally used; but at present the very first is employed almost exclusively.

In the commercial manufacture of chlorine manganese peroxide, generally pyrolusite, is treated with hydrochloric acid in a closed oblong stone box. The chlorine escapes through a pipe into a main.

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[a] Thorp, F. H., Outlines of industrial chemistry.

The hydrochloric acid is run in through a funnel tube, which empties into a bowl filled with acid, so that no chlorine escapes through it. The action goes on without heating for some time, and when it slackens steam is blown in from time to time.

Very pure pyrolusite must be used, as some impurities, carbonates, for example, tend to waste the acid and add objectionable gases, and others, such as silica and other insoluble materials, obstruct the action of the acid. Ferrous iron, if present, not only uses up acid, but absorbs oxygen. Soft ore is more easily treated than hard ore.

The reaction taking place in the still is the same as that given above, except that as pyrolusite is not pure MnO_2 the remaining product, or "still liquor," contains small quantities of other compounds.

The following analysis by Black[a] gives the general composition of "still liquor:"

Composition of "still liquor" in process for production of chlorine.

$MnCl_2$	10.5700
Al_2Cl_6	.6200
Fe_2Cl_6	.4551
HCl (undecomposed)	6.6220
H_2O	81.7329
	100.0000

In former years this liquid was allowed to go to waste, thus necessitating a fresh supply of pyrolusite every time the still was charged. As this was expensive, methods were devised by which the manganese chloride in the still liquor was converted into peroxide and used again. The first of these to be successful was discovered by Charles Dunlop in 1855. In the Dunlop process the still liquor is mixed with ground chalk or limestone dust and the free acid is neutralized with the formation of calcium chloride and carbonic acid, while the iron is precipitated as hydrated oxide. The neutral liquid, consisting of manganous and calcium chlorides, after settling, is pumped into large boilers supplied with agitating shafts, and more chalk is mixed with it. Steam is then blown in until a pressure of 2 to 2½ atmospheres is reached. In about twenty-four hours a chemical reaction takes place between the calcium carbonate and manganous chloride, resulting in the production of manganous carbonate and calcium chloride, thus:

$$CaCO_3 + MnCl_2 = MnCO_3 + CaCl_2.$$

The manganese carbonate is then washed, pressed, and partly dried, and placed in a furnace. The temperature is gradually raised to 315° C. A draft runs through the furnace and the manganese carbonate is occasionally splashed with water. After about twenty-four hours of heating the carbonate is changed to a mixture of oxides consisting of about 72 per cent peroxide of manganese, 26 per cent lower oxides of manganese, and 2 per cent calcium oxide. This material is used again in the still.

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[a] Newth, G. S., Text-book of inorganic chemistry, 1908, p. 357.

In 1867 another process was discovered by Walter Weldon, which, being much less expensive than the Dunlop process, has now completely replaced it. In the Weldon process, the neutralization of the liquid is accomplished in the same way as described above, and the resulting manganous and calcium chlorides are pumped into a settling tank. The clear liquid is drawn off through a pipe into a large iron cylinder without disturbing the sediment. In this cylinder, called the "oxidizer," it is mixed with milk of lime (calcium hydroxide) and manganous hydroxide, $Mn(OH)_2$, is precipitated. The mixture now consists of manganous and calcium hydroxides and some calcium chloride. A stream of compressed air is then forced into the cylinder, oxidizing the manganese and converting it largely into calcium manganite, $CaO.MnO_2$. By further addition of the neutral liquid from the settling tank, and by raising the temperature within the oxidizer by injecting steam, some of the material is converted into a compound which has the composition $CaO_2.MnO_2$. The contents are then run into settling tanks and the product settles as a thin black mud known as "Weldon's mud." This is used again in the chlorine stills.

The most valuable property of chlorine, from a commercial standpoint, is its bleaching power. For this purpose it is combined with slaked lime to form bleaching powder (chloride of lime), and reliberated, when ready to be used, by treatment with dilute hydrochloric acid.

Chlorine bleaches all materials dyed with organic colors. This is performed in the presence of water, the chlorine combining with hydrogen and liberating oxygen, which oxidizes the coloring materials. Its use consists in bleaching vegetable fiber, as cotton, hemp, etc., as well as manufactured cloths, and old rags for paper manufacture. It is also used as a disinfectant and deodorizer for sanitary purposes, and as an oxidizer in many other ways.

MANUFACTURE OF BROMINE.

The action of manganese peroxide in the manufacture of bromine is the same as in the case of chlorine. Many saline springs, besides containing various chlorides, contain bromides, mainly of magnesium, but also of calcium, potassium, and sodium. In preparing bromine this brine is partly evaporated, and most of the chlorides are precipitated and removed, leaving a mother liquor containing some chlorides and the bromides. The mother liquor is mixed with manganese peroxide and sulphuric acid, which act upon the chlorides remaining with the evolution of chlorine, which in turn decomposes the bromides, displacing the bromine.

$$MgCl_2 + MnO_2 + 2H_2SO_4 = MnSO_4 + MgSO_4 + 2H_2O + Cl_2.$$
$$MgBr_2 + Cl_2 = MgCl_2 + Br_2.$$

The bromine is condensed in passing through a worm condenser.

MANUFACTURE OF OXYGEN.

Various compounds of manganese are used in generating oxygen. Manganese peroxide, when heated to redness, gives up one-third of its oxygen:

$$3MnO_2 = Mn_3O_4 + O_2.$$

Potassium chlorate, when heated considerably above the melting point, gives up its oxygen with effervescence:

$$KClO_3 = KCl + O_3.$$

When previously mixed with about one-fourth of its weight of MnO_2, however, it gives up all its oxygen considerably below the melting point, and at the end of the reaction the MnO_2 is found to be unchanged. In this case manganese peroxide acts as a catalytic agent, and it is believed that it goes through a series of reactions before the final product is evolved. The power possessed by manganese to enter into higher states of oxidation is believed first to result in the formation of potassium permanganate:

$$2MnO_2 + 2KClO_3 = 2KMnO_4 + Cl_2 + O_2.$$

The potassium permanganate passes into potassium manganate with evolution of oxygen and partial reformation of manganese peroxide—

$$2KMn_4O = K_2MnO_4 + MnO_2 + O_2;$$

and finally potassium manganate is decomposed by the chlorine evolved in the first reaction into potassium chloride, manganese dioxide, and oxygen:

$$K_2Mn_4O + Cl_2 = 2KCl + MnO_2 + O_2.$$

Manganese peroxide parts with half of its oxygen when heated with sulphuric acid:

$$MnO_2 + H_2SO_4 = MnSO_4 + H_2O + O.$$

Potassium permanganate, as well as other highly oxidized salts, yields oxygen when acted upon by sulphuric acid:

$$2KMnO_4 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 3H_2O + 5O.$$

If hydrogen peroxide be added to dilute sulphuric acid and the mixture be added to potassium permanganate, a rapid evolution of oxygen takes place:

$$2KMnO_4 + 3H_2SO_4 + 5H_2O_2 = K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2.$$

DISINFECTANTS.

Manganates and permanganates are extensively used as disinfectants and oxidizers on account of the readiness with which they give up their oxygen to organic and other oxidizable compounds. The oxygen combines with and carries off injurious elements in decaying material. Sodium permanganate ($NaMnO_4$), under the name of "Condy's disinfecting fluid," is largely used for this purpose.

DECOLORIZER OF GLASS.

In the manufacture of glass, the sand and other materials used almost invariably have a small quantity of iron impurities, as a result of whose presence the glass has a green color. This color is due to the iron existing in the ferrous state, and is removed by mixing the glass with peroxide of manganese during its manufacture. Two explanations are given for this action. It is thought by some that part of the oxygen in the peroxide of manganese is released and unites with the ferrous iron, making it ferric and changing the color from green to a scarcely perceptible yellow. Others believe that the purple color caused by manganese neutralizes the green caused by the iron, and that no chemical reaction takes place. If too much manganese peroxide is used, or not sufficient heat, the glass is likely to receive a pink or violet color. The same coloration appears in glass long exposed to sunlight.

DRYER IN PAINTS AND VARNISHES.

When manganese peroxide is immersed for some time in oils used for paints and varnishes, and then removed, it is found that the drying qualities of the oil are greatly increased. After being dried and exposed to the air, the manganese peroxide is ready to be used again. It is maintained that the manganese peroxide gives up some of its oxygen to the oil and on exposure to the atmosphere takes up a fresh supply. It is possible, however, that the oxygen is carried from the air into the oil by being mechanically held in the interstices of the peroxide. Manganese metaborate, $Mn(BO_2)_2$, also is used in the preparation of drying oils and oil varnishes.

LECLANCHÉ CELL.

An electric cell is essentially composed of two metals immersed in a liquid, in which one is soluble and one relatively insoluble. In the Leclanché cell the liquid is ammonium chloride, the soluble metal zinc, and the insoluble element carbon. Ammonium chloride attacks the zinc and forms a salt of that metal, at the same time liberating hydrogen, which settles on the carbon and soon retards the action of the cell. Peroxide of manganese is used as a coating of the carbon, or is mixed with it, so that, when the hydrogen comes in contact with it, the peroxide of manganese gives up part of its oxygen, converting the hydrogen into water, and being itself converted into a lower oxide. The peroxide of manganese has to be renewed occasionally.

In continuous work the Leclanché cell soon becomes polarized and loses strength, but rapidly regains it when left at rest. For this reason, it is not adapted for closed-circuit work like telegraphy, but is well fitted for open-circuit work, as in telephones and electric bells, and is extensively used for these purposes.

DRY CELL.

Manganese peroxide is used extensively in the manufacture of Bamboni's dry cell.[a] To prepare such a cell a piece of paper is tinned or silvered on one side and coated on the other with finely powdered manganese peroxide, which is moistened and rubbed on with a cork. The manganese powder used must contain 82 to 92 per cent available MnO_2, must be free from iron oxides, and must be ground to a fineness varying from 30 or 40 mesh down to a fine powder.[b] A number of sheets thus coated are placed one on top of another, the tinned or silvered side of one in contact with the manganese peroxide coated side of the next. They are then cut by a punch into disks an inch in diameter, and these disks are arranged in the same way. When 1,200 or 1,800 couples have been piled up, they are placed in a glass tube with a brass cap at each end, which contains a rod and knob for pressing the leaves together to insure a good contact. The knob in contact with the manganese peroxide corresponds to the positive pole of the cell, while the other is the negative pole. Dry cells are remarkable for their duration of action, which may go on for several years.

MISCELLANEOUS.

Potassium permanganate powder, when mixed with organic substances, is subject to spontaneous combustion and is used as an explosive. It is also used in a slightly acid solution for bleaching cotton that has been boiled in caustic soda to remove gums and oily matters. The cloth is deep brown when removed from the bath, but on passing through sodium disulphate or sulphuric acid it becomes pure white.

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[a] Atkinson, E., Ganot's Physics, p. 829.

[b] Burgess, C. F., personal correspondence.

USES AS A COLORING MATERIAL.

Various compounds of manganese, on account of the quality and fast nature of their color, are used for dyeing, for painting, and other coloring purposes.

CALICO PRINTING AND DYEING.

Manganese brown, a color used in dyeing cotton, consists of the hydroxide or oxide of manganese. It is obtained by steeping the goods in a solution of manganous chloride or acetate, free from acid, and developing the oxide in a mixed solution of caustic soda and bleaching powder.

Manganese brown is fast against light, soap, and dilute acids and alkalies, and is used plain or serves as a ground on which to print figures of other colors, these being so composed as to remove the brown immediately under them. It is used also as a base on which to dye aniline blacks, the oxide in the fiber assisting in oxidizing the aniline.

A deep brown is obtained by passing the goods through a bath containing potassium permanganate and sodium carbonate solutions.

COLORING OF GLASS, POTTERY, AND BRICKS.

A small amount of manganese peroxide free from iron will give a pink or violet color to glass. An excess of pyrolusite, especially if iron is present, causes a deep yellow or brown, while a large excess of pyrolusite, with iron and copper oxides, produces a black color. A red color may be obtained by adding certain mixtures of pyrolusite and sesquioxide of iron.

Pottery and bricks also are colored by manganese peroxide. Black and various shades of brown are produced in the glaze of pottery by mixtures of manganese peroxide and oxides of iron. Black door knobs contain an excess of pyrolusite. Wad and other low-grade oxides of manganese are used for giving bricks a chocolate color; pyrolusite and psilomelane are used in giving the spots to fancy speckled bricks and in coloring red bricks brown and buff-colored bricks gray.

The use of manganese in the brick industry has become of considerable importance in recent years on account of the increased use of fancy colored brick in architecture. The ore used in this connection, after being thoroughly washed and concentrated, is crushed into granules or ground into a fine powder, according as it is to be used in the manufacture of speckled brick or of brown and gray brick. In these forms it is shipped to the brickmakers.

In order to insure uniform results in the coloring of brick the manganese is generally prepared into a "stock stain," formed by mixing one part of manganese ore with nine parts of clay. This mixture may have a thin consistency when powdered manganese ore is used, but should be fairly thick when the granulated material is used, so as to prevent the heavy manganese from settling to the bottom. The "stock stain" is mixed with the brick clay in proportion to the depth of color desired in the finished product. Only a very small quantity of manganese is required, a 2 per cent mixture being commonly used. The degree of heat also affects the depth of color; the greater the heat the darker will be the color of the brick. Extreme care must be exercised both in the mixing of the materials and in regulating the temperature of the kilns.

PAINTS.

Wad is used in the crude state as a pigment in some chocolate and brown paints. "Manganese green" is a barium manganate prepared by mixing three or four parts of caustic baryta moistened with water, two parts of manganese oxide, and two parts of barium nitrate, and fusing it in a crucible already heated to redness. It is then digested in hot water, washed in cold water, and dried in an atmosphere free from carbonic acid. "Nuremberg violet" also is prepared from compounds of manganese.

MISCELLANEOUS.

Mottled soap is colored by oxide of manganese. Potassium permanganate is used for giving a deep-brown stain to wood.

MINOR USES.

Manganese protoxide is used to a slight degree as a mordant in fixing a color on cloth fiber by its affinity for it. The goods are treated with potassium permanganate and then subjected to a strong reducing agent, causing the precipitation of the hydrated protoxide, after which they are ready to hold the required dye.

Rhodonite commonly has a beautiful pink color and such rhodonite is used for jewelry or ornamental stone. Sulphate of manganese and potassium permanganate are used in medicine, and small quantities of all the manganese compounds are used in chemical laboratories. Potassium permanganate is used for purifying carbon dioxide and ammonia gases.

CHAPTER VI.

THE MANGANESE INDUSTRY IN THE UNITED STATES.

PRODUCTION OF ORES.

The manganese mining industry in the United States is reported to have begun about 1837, but the production previous to 1865 was insignificant. From 1865 to 1883 there was a small annual production, but immediately after that the industry received a great impetus. The maximum yearly production of 34,524 tons was reached in 1887 and was followed by a slow decline to 6,308 in 1894. Subsequently there was a slight increase followed by a still greater decline, the minimum (2,825 tons) being reaches in 1903. At present the prospects are favorable for an increased annual production.

HISTORY OF PRODUCTION BY STATES.

The history of the industry is taken up by States, given in the order in which they appeared as producers.

Tennessee.—The first manganese mining in the United States of which there is any record was done near Whitfield,[a] Hickman County, Tenn., in 1837. Small quantities, measurable in pounds, have been mined occasionally at this locality in succeeding years and used for coloring earthenware, but the total production has been insignificant. In 1886 a small intermittent production of manganese and manganiferous iron ores began in eastern Tennessee and has continued to the present time. The mining operations have been mainly[b] in Unicoi, Cocke, and Monroe counties and in Shady Valley. Operations are at present conducted near Del Rio, Cocke County, by Col. John N. Adams.

Arkansas.—About 1850 to 1852 mining operations were begun on a small scale in the Batesville district of Arkansas, ore being shipped by Col. Matthew Martin[c] from lands near Cushman. Up to 1880 small quantities continued to be mined at intervals, but large shipments were not begun until 1881.[d] The first ore from this district for use in steel manufacture consisted of about 10 tons shipped by William Einstein, of St. Louis, in 1868, to the Juniata Iron Works at Pittsburg. In 1881 the Batesville district became a regular producer of manganese and continued so until 1903, although several years before that the production had dwindled considerably. There was a small production in 1906, but at present the mines are idle. The stimulus in 1881 was caused by the appearance of Mr. E. M. Woodward of the Ferromanganese Company, who had already gained considerable experience in the Appalachian region, and who worked in Arkansas the Southern, Turner, Trent, Montgomery, and other mines. In 1885 the Keystone Iron and Manganese Company commenced operations at the Southern mine, and in 1888 the predecessors of John B. Skinner & Co. began to open up properties in the southern part of the district. The period of greatest production in Arkansas was between 1884 and 1898. In recent years a considerable amount of manganiferous iron ores has been mined at the Cason mine in this district by the Frisco Ore Mining Company of St. Louis.

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[a] Penrose, R. A. F., jr., Manganese: Its uses, ores, and deposits: Ann. Rept. Geol. Survey Arkansas for 1890, vol. 1, p. 58.

[b] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 424.

[c] Penrose, R. A. F., jr., op. cit., p. 57; also Weeks, J. D., Mineral Resources U. S. for 1885 and 1888.

[d] Penrose, R. A. F., jr., op. cit., pp. 62-63.

Vermont.—In the later fifties shipments of manganese ore to England began from the Brandon and Chittenden areas of Vermont.[a] Although for many years iron ores had been mined at these localities, the associated manganese ores had been avoided, as it was supposed that they were harmful to the iron. The amount mined in succeeding years, however, was very small and was not recorded. In 1887, 1888, 1889, and 1891 manganiferous iron ore was mined at South Wallingford, and in 1897 1,200 tons of similar ore were produced. Since then no manganese-ore production has been reported from the State.

Virginia.—The production of manganese ore in Virginia began in 1859,[b] when Mr. Sibert prospected and opened up several localities in the valley of Virginia, among which were the Lyndhurst and Kennedy mines. The amount of ore mined, however, was very small. About the same time manganiferous iron ore was being mined in the State in small quantities.

In 1867 Mr. James E. Mills began a systematic search for manganese in the eastern United States in the interests of a firm in Newcastle, England. He opened up the Cabell mine in the James River valley in Virginia and in the following years shipped 4,500 tons of manganese ore from this mine to England to be used in chlorine works.

The year 1867 also marked the opening of the Crimora mine in the valley of Virginia. It was worked by a stock company for several years; then operations were suspended and until 1882 only occasional small quantities were mined. In 1882 it was leased by James B. White & Co. of Pittsburg, and operations were begun on a large scale. Later it was acquired by the American Manganese Company. During these years the Crimora mine was the greatest producer of manganese in this country and perhaps in the world. About 1892 underground operations were discontinued and a system installed for surface hydraulic mining. This has never been fully tested, and since its installation mining at Crimora has been intermittent and conducted on a small scale.

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[a] Penrose, R. A. F., jr., op. cit., p. 59.

[b] Idem, pp. 58-61.

Since 1880 a large number of mines have been opened and operated in Virginia, both in the Piedmont region and in the valley of Virginia. Among them are the Mount Athos, Bugley, Midvale, Houston, and Vesuvius mines. Considerable high-grade manganese ore was produced at the Houston mine in the late eighties, at which time it was being operated by James B. White & Co. The Lyndhurst and Kennedy mines have continued to be fairly regular producers. In recent years Kendall & Flick, of Washington, D. C., have done much toward developing properties in the valley of Virginia, having operated ore banks near Elkton, Grottoes, and Lithia.

At present the Piedmont Manganese Company, D. W. Myers, of Lynchburg, president, is conducting operations on a small scale southeast of Lynchburg, the ore being used for coloring brick. The Metallic Alloys Company, of Elkton, successor to Kendall & Flick, is operating the Lyndhurst mine and others in the valley of Virginia, and the Manganese Corporation of Virginia is operating the Vesuvius mine. Small quantities of ore are being mined at the Dry Run mine near Compton, at the Theresa mine near Otter River, at the Crimora mine, and in the New River region.

The Virginia production was greatest between 1884 and 1892, when the Crimora mine was being worked on a large scale. Since 1892 small quantities ranging between 1,000 and 8,000 tons have been produced annually. Manganiferous iron ores have been mined intermittently at many of the iron-ore deposits.

Georgia.—Manganese mining began in the Cartersville district of Georgia in 1866 with the production of 550 tons of ore. In 1867 the Dobbins mine in this district was opened, and in following years other properties were exploited. Since 1867 a large number of mines have been opened and operated in the Cartersville district, in the Cave Springs district, and at Tunnel Hill, Ga. The Dobbins mine was leased by E. H. Woodward in 1885 and together with other mines of the district was actively worked for a number of years. Both the Cartersville and the Cave Springs districts were regular producers of manganese ore until about 1903, but since then no ore has been mined except 150 tons in 1905.

A small production of manganiferous iron ore was reported from Georgia in 1887, but there has doubtless been more of this ore produced which has not been recorded as such.

California.[a]—The production of manganese ore began in California in 1867, with the opening of the old Ladd mine in San Joaquin County and deposits on Red Rock Island in San Francisco Bay.

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[a] Penrose, R. A. F., jr., op. cit., pp. 60–61.

Mining was started at the old Ladd mine by Mr. A. S. Ladd and was continued by him until 1874, up to which time about 5,000 tons of ore was shipped to England, together with a small quantity of ore from Red Rock Island. In 1875 the old Ladd mine was purchased by Mr. Justinian Caire, of San Francisco, and shortly afterward work was stopped because of the inability to compete in England with Spanish manganese ore.

In 1882 a small deposit near Sausalito was opened and operated on a small scale, the ore being used as flux in a local smelter. Since then a number of small deposits have been discovered and opened in Alameda, Santa Clara, and San Joaquin counties, but very little ore has been produced.

New Jersey.—Neither manganese ores nor manganiferous ores used for their manganese content have been produced in New Jersey. Since 1870, however, the residuum of the manganiferous zinc ores which remains after the zinc oxide is roasted off has been utilized in the manufacture of ferromanganese and spiegeleisen. The production of this material was not recorded until 1889, but since that time there has been a steady increase.

Alabama.—Small quantities of manganese ores were mined in Alabama in 1886, 1898, and 1901. The product of 1886 was obtained from Cleburne County, in the vicinity of Stocks Mills.[a]

As early as 1875 manganiferous iron ores were mined at Woodstock,[a] Bibb County, and used in the manufacture of spiegeleisen at the Woodstock furnaces, at Anniston, Calhoun County. It is said to have been the first domestic ore used for this purpose.

Missouri.—Considerable amounts of manganese and manganiferous iron ores are said to have been mined in the Pilot Knob district in Missouri for use in the St. Louis furnaces.[b]

In 1881, at Arcadia, Iron County, 2,000 tons of manganiferous iron ore were mined and manufactured into an iron with 0.75 per cent manganese. This production has not been recorded as a manganiferous iron ore, but as an iron ore. Small quantities of manganese ore were produced in 1899 and 1901.

Lake Superior region.—A large quantity of manganiferous iron ore is mined annually in the Lake Superior iron district. The ore is so low in manganese, however, that it is not used in the manufacture of spiegeleisen or ferromanganese, but it yields a manganiferous pig iron of a somewhat different nature from ordinary pig iron. Small quantities of high-grade manganese ore were shipped from Michigan in 1888 and in 1897.

North Carolina.—Small quantities of manganese and manganiferous iron ores have occasionally been mined in North Carolina for development purposes[a] and in connection with iron ores, but the total amount produced has been very small.

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[a] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 400-401.
[b] Idem, p. 416.

Maine.—Maine produced 50 tons of manganiferous iron ore in 1887. This is the only production reported from that State.

South Carolina.—South Carolina produced manganese ore in 1889, 1902, 1903, and 1907, the product of the last year being greater than the entire amount mined previously in this State.

Pennsylvania.—Manganese and manganiferous iron ores in small quantities have been produced intermittently in Pennsylvania where they occur largely in connection with the iron-ore deposits.

Colorado.—Colorado has produced no manganese ore proper, but considerable manganiferous silver ore from the Leadville district, and from Gilman, Eagle County, has been shipped to Pueblo and even to Chicago, and manufactured into spiegeleisen and ferromanganese. This practice began late in the eighties[b] and has continued to the present. Large quantities of the same ore have been sent to smelters to be used for flux in lead and silver smelting.

Montana.—During the eighties manganiferous silver ores were being mined in Montana and used for flux by the Butte smelters. A considerable tonnage was reported in 1885, a part of which probably came from the Butte district. Similar ores were mined at Neihart[c] in 1893 and 1894, and sold as flux to the smelters at Great Falls. In 1900 there were 37 tons of manganese ore mined.

Nevada.[b]—Nevada produced small amounts of ore from 1885 to 1890. Part of it came from the Golconda deposit; the source of the rest is not known. Considerable manganiferous silver ore occurs in this State, but none has been reported as being used for its manganese content.

Oklahoma.—In 1891 a small quantity of ore was mined at Lehigh,[d] Ind. T., this being the only manganese ore produced by Oklahoma. The ore was shipped to the Illinois Steel Company.

South Dakota.[e]—South Dakota was a producer of manganese only for one year, 1891. The ore was from Custer County.

West Virginia.—Manganese ores were produced in West Virginia between 1894 and 1899, being obtained partly[f] if not entirely from Glenmore, Greenbrier County.

Maryland.—Maryland is reported[g] to have produced manganese ores, but none have been recorded.

Utah.—Manganese mining began in Utah in 1901, when the deposit near Little Grande was opened up by the Colorado Fuel and

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[a] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 420.

[b] Penrose, R. A. F., jr., op. cit., p. 64.

[c] Weeks, J. D., op. cit., p. 418.

[d] Idem, p. 413.

[e] Idem, p. 423.

[f] Idem, p. 434.

[g] Penrose, R. A. F., jr., op. cit., p. 61.

Iron Company. Since then small amounts have been shipped from this locality, but at present the mines are not being operated. Other manganese deposits are being exploited in Utah, but there has been no production from them. Manganiferous silver ores occur in a few localities, but have not been mined for their manganese content.

New Mexico.—Considerable manganiferous iron ore has been produced at Silver City, N. Mex. This ore is too low in manganese to be used for that metal, but contains a high percentage of iron and so is classed with iron ores. In 1907 there was produced of this ore 7,000 tons, which had an iron content of 46 per cent and a manganese content of 6 per cent.

PRODUCTION TABLES.

The following tables show the production of manganese ores, manganiferous ores, and manganiferous zinc residuum in the United States as far as known:

Production of manganese ore in the United States, 1838-1908, in long tons.

Year.	Alabama.	Arkansas.	California.	Georgia.	Oklahoma (Ind. T.)	Michigan.	Missouri.	Montana.	Nevada.	North Carolina.	Pennsylvania.	South Carolina.	South Dakota.	Tennessee.	Utah.	Vermont.	Virginia.	West Virginia.	Other States.	Total.
1838-1879		410																		410
1866-1879				19,950																19,950
1867-1879			5,500														18,000			23,500
1880				1,800													3,661		300	5,761
1881		100		1,200													3,295		300	4,895
1882		175		1,000													2,982		375	4,532
1883		400															5,355		a 400	6,155
1884		800															8,980		a 400	10,180
1885		1,483	200	2,580					200								18,745		50	23,258
1886	75	3,316	100	6,041					30	14				50			20,567			30,193
1887		5,651		9,024						14							19,835			34,524
1888		4,312	1,500	5,568		100					22						17,646		b 50	29,198
1889		2,528	53	5,208					15	47		124		30		1,576	14,616			24,197
1890		5,339	386	749					100	14							12,699			19,287
1891		1,650	705	3,575	206								19			49	16,248			22,452
1892		6,708		826													6,079			13,613
1893		2,020	400	724										482			4,092			7,718
1894		1,934	278	1,277										922			1,797	100		6,308
1895		2,991	525	3,856							460						1,715			9,547
1896		3,421	284	4,085						2	265						2,018	13		10,088
1897		3,240	484	3,332		37					354			11			3,650			11,108
1898	22	2,662	541	6,689										381			5,662			15,957
1899		356	115	3,089			16			90	12			19			6,228	10		9,935
1900		145	131	3,447				137						30			7,881			11,771
1901	17	91	610	4,074			28							400	2,500		4,275			11,995
1902		82	846	3,500								8					3,041			7,477
1903			16	500								25			483		1,801			2,825
1904			60												32		3,054			3,146
1905			1	150										20			3,947			4,118
1906		62	1											30	800		6,028			6,921
1907			100									800		100			4,604			5,604
1908																	6,144			6,144
	114	49,876	12,836	92,244	206	137	44	137	345	181	1,113	957	19	2,475	3,815	1,625	234,645	123	1,875	402,767

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[a] Georgia and North Carolina.

[b] Nevada, North Carolina, South Carolina, Tennessee, and Vermont.

Production of manganiferous ores in the United States, 1885–1908, in long tons.

Year.	Arkansas.	Colorado.[a]	Colorado.[b]	Georgia.	Lake Superior region.	Maine.	Montana.	North Carolina.	New Mexico.	Pennsylvania.	Vermont.	Virginia.	Total.
1885							4,263						4,263
1886			[c] 60,000		257,000								317,000
1887			[c] 60,000	195	210,000	50					481	1,025	271,751
1888			[c] 60,000		201,036			[d] 96			1,000		262,132
1889			64,987		81,359								146,346
1890		6,397	51,840		61,863								120,100
1891		964	79,511		132,511								212,986
1892		2,942	62,309		147,431							3,000	215,682
1893	160	5,766	54,462		110,648		1,500	20				1,188	173,744
1894		7,022	30,187		198,466		1,500						237,175
1895		13,464	54,163		112,265								179,892
1896		9,072	138,079		329,640								476,791
1897		16,519	149,502		184,585						1,200		351,806
1898		18,848	99,651		268,862					100			387,461
1899		29,355	79,855		732,490								841,700
1900		43,303	188,509		334,274								566,086
1901		62,385	228,187		512,084			20					802,676
1902		13,275	194,132		884,939							3,000	1,095,346
1903		14,856	179,205		566,835							2,802	763,698
1904	600	17,074	105,278		365,572								488,524
1905	3,321	45,837	81,738		720,098								850,994
1906	8,900	32,400	([e])		[f] 1,000,000								[f] 1,041,300
1907	4,133	67,514	32,197		314,316				7,000				425,160
1908	4,066	15,973	35,581		467,140							274	523,034
	21,180	422,966	2,089,373	195	8,193,414	50	7,263	136	7,000	100	2,681	11,289	10,755.647

[a] Manganiferous silver ore used in the manufacture of spiegeleisen and ferromanganese.

[b] Manganiferous silver ore used for flux; mainly from Colorado, but in a few cases including ore from other Western States.

[c] Contains some Montana ore.

[d] Contains some South Carolina and Tennessee ore.

[e] Not recorded.

[f] Estimated.

Production of manganiferous residuum from zinc roasting in the United States, 1889–1908, in long tons.[a]

1889	43,648	1900	87,110
1890	48,560	1901	52,311
1891	38,228	1902	65,246
1892	31,859	1903	73,264
1893	37,512	1904	68,189
1894	26,981	1905	90,289
1895	43,249	1906	93,461
1896	44,935	1907	93,413
1897	33,924	1908	110,225
1898	48,502		
1899	65,010		1,195,916

The following tables show the quantity and value of manganese ores, manganiferous ores, and manganiferous zinc residuum produced in the United States during 1905, 1906, 1907, and 1908:

Production and value of manganese ores in the United States, 1905–1908, by States.

State.	1905.			1906.		
	Quantity, long tons.	Value.	Average price per ton.	Quantity, long tons.	Value.	Average price per ton.
Arkansas				62	$290	$4.68
California	1	[a] $5	$5.00	1	20	20.00
Georgia	150	[a] 900	6.00			
South Carolina						
Tennessee	[a] 20	[a] 100	5.00	30	300	10.00
Utah				800	10,000	12.50
Virginia	[b] 3,947	35,209	8.92	6,028	77,522	12.86
	4,118	36,214	8.80	6,921	88,132	12.73

State.	1907.			1908.		
	Quantity, long tons.	Value.	Average price per ton.	Quantity, long tons.	Value.	Average price per ton.
Arkansas						
California	100	$600	$6.00			
Georgia						
South Carolina	800	4,800	6.00			
Tennessee	100	1,500	15.00			
Utah						
Virginia	4,604	56,469	12.27	6,144	$62,779	$10.22
	5,604	63,369	11.31	6,144	62,779	10.22

[a] Estimated. [b] In addition, 453 tons of tailings, valued at $406, were shipped.

Production and value of Colorado manganiferous silver ores used in the manufacture of ferromanganese and spiegeleisen, 1905–1908, in long tons.

Year.	Percentage of manganese.	Quantity.	Value.	Average price per ton.
1905	14–41	45,837	$110,497	$2.41
1906	26–36	32,400	97,600	3.01
1907	10–25	67,514	153,328	2.27
1908	22–26	15,973	39,468	2.47
	10–41	161,724	400,893	2.48

[a] The manufacture of spiegeleisen from manganiferous residuum was begun in 1870, but there is no record of the amount of raw material used prior to 1889.

Production and value of manganiferous ores used for fluxing or other purposes in Colorado and Arkansas, 1905–1908, in long tons.

Year.	State.	Percentage of manganese.	Quantity.	Value.	Average price per ton.
1905	Arkansas	28	3,321	$6,642	$2.00
	Colorado		81,738	270,299	3.31
1906	Arkansas	20-25	8,900	24,800	2.79
1907	Arkansas	14	4,133	8,266	2.00
	Colorado	8-26	32,197	[a] 97,879	3.04
1908	Arkansas	14	4,066	9,149	2.25
	Colorado	6-22	35,581	83,939	2.36
		6-28	169,936	500,974	2.95

[a] Partly estimated.

Production and value of manganiferous zinc residuum in the United States, 1905–1908, in long tons.

Year.	Quantity.	Value.	Average price per ton.
1905	90,289	$90,289	$1.00
1906	93,461	93,461	1.00
1907	93,413	280,239	3.00
1908	110,225	330,675	3.00
	387,388	794,664	2.05

PRICES OF ORES.

The prices of manganese ores used in the steel industry vary from $5 to $15 per long ton, according to the grade of the ore. They are governed by the following schedule of prices established by the Carnegie Steel Company:[a]

Schedule of prices paid per ton of 2,240 pounds for domestic manganese ore delivered at Pittsburg or Bessemer, Pa., and South Chicago, Ill.

Prices are based on ores containing not more than 8 per cent silica or 0.20 per cent phosphorus, and are subject to deductions as follows: For each 1 per cent in excess of 8 per cent silica there shall be deduction of 15 cents per ton; fractions in proportion.

For each 0.02 per cent, or fraction thereof, in excess of 0.20 per cent phosphorus there shall be a deduction of 2 cents per unit of manganese per ton.

Percentage of metallic manganese in ore.	Price per unit in cents.	
	Manganese.	Iron.
Over 49	26	5
46 to 49	25	5
43 to 46	24	5
40 to 43	23	5

Ores containing less than 40 per cent manganese or more than 12 per cent silica or 0.225 per cent phosphorus are subject to acceptance or refusal at the buyer's option.

Settlements are based on analysis of sample dried at 212° F., the percentage of moisture in the sample as taken being deducted from the weight.

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[a] Prices of manganese ore: Eng. and Min. Jour. March 5, 1910.

The manganese ores for oxidizing and coloring purposes are valued according to the quantity of manganese peroxide present, their consistency, etc., and prices range up to $35 per ton for the better grades of ore. Manganiferous ores used in steel manufacture and for fluxing range in price from $2 a ton upward.

IMPORTATION OF ORES.

Large quantities of manganese ores, compared with which the domestic production is insignificant, are annually imported into the United States from foreign countries. They are being obtained at present largely from India, Brazil, and Cuba, with smaller amounts from Germany, Great Britain, Russia, East Indies, France, the Netherlands, Belgium, Spain, Japan, Canada, and other countries.

Before about 1886[a] manganese ores were imported into this country mainly from Canada and Spain, but at that time shipments commenced from Cuba, Chile, and Russia, as well as Greece and Turkey. For many years Russian ores constituted by far the largest portion of the imported product, but in late years imports from both India and Brazil have exceeded them in quantity, until at present the manganese-ore imports from Russia are almost insignificant. Small amounts of manganese ore have been imported annually from Germany, Great Britain, Japan, and Belgium.

The following table shows the total quantity of manganese ore imported into the United States as far as has been recorded. The figures from 1868 to 1888 represent imports from Canada only. Those from 1889 to the present time represent total imports.

Imports of manganese ore into the United States, 1868–1908, in long tons.

Year ending June 30—	
1868	1,017
1869	488
1870	1,402
1871	1,056
1872	1,206
1873	838
Year ending December 31—	
1873	1,031
1874	782
1875	203
1876	412
1877	891
1878	626
1879	1,886
1880	2,179
1881	1,704
1882	894
1883	1,326
1884	603
1885	1,684
1886	1,818
1887	1,630
1888	1,182
1889[b]	4,286
1890	34,154
1891	28,825
1892	58,572
1893	68,113
1894	44,655
1895	86,111
1896	31,489
1897	119,961
1898	114,885
1899	188,349

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[a] Penrose, R. A. F., jr., op. cit., p. 69.

[b] Figures prior to 1889 represent imports from Canada only, total importations from other countries for these years not being obtainable.

Imports of manganese ore into the United States, 1868–1908, in long tons—Continued.

Year ending December 31—		Year ending December 31—	
1900	256,252	1906	221,260
1901	165,722	1907	209,021
1902	235,576	1908	178,203
1903	146,056		[a] 2,581,900
1904	108,519		
1905	257,033		

The following tables, compiled from statistics furnished by the Bureau of Statistics, Department of Commerce and Labor, show the imports of manganese ore into the United States from different countries and by ports of entry for 1905, 1906, 1907, and 1908:

Imports of manganese ores into the United States, 1905–1908, by countries, in long tons.

Country.	1905.		1906.		1907.		1908.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Brazil	114,670	$1,058,478	30,260	$300,466	52,922	$522,510	17,150	$163,561
Russia	24,650	202,774	13,805	109,814	1,000	19,570	250	4,509
British India	101,030	501,423	154,180	939,984	95,300	552,228	143,813	912,646
Cuba	6,489	35,049	11,701	117,050	30,006	262,847	1,469	13,489
East Indies					12,552	82,832	7	170
France					1,588	31,536	5,546	75,857
Netherlands					1,795	35,473	761	11,265
Japan	1,329	13,950	2,000	21,664	1,787	15,020	3,336	41,930
Germany	2,336	54,150	4,386	112,511	6,702	150,388	2,620	62,045
United Kingdom	1,298	30,555	1,330	37,711	3,999	96,833	2,973	59,092
Canada	7	575	112	1,125	16	500	73	1,245
Spain	50	708						24
Belgium	80	1,762	1,710	30,377	1,354	23,406	202	4,214
All other countries	5,094	52,983	1,776	25,341			3	86
	257,033	1,952,407	221,260	1,696,043	209,021	1,793,143	178,203	1,350,223

Manganese ores imported into the United States, 1905–1907, by customs districts, in long tons.

Customs districts.	1905.		1906.		1907.		1908.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Philadelphia, Pa	117,591	$822,525	93,590	$682,485	106,494	$888,239	68,491	$504,094
Baltimore, Md	126,018	993,163	120,051	860,112	92,331	694,732	103,043	724,913
New York, N. Y	5,954	90,942	6,802	136,037	7,867	177,323	5,963	105,665
Chicago, Ill	20	496	239	10,096	266	11,839		
Boston, Mass	4	127	5	209			5	280
New Orleans, La	199	1,822	411	3,675	1,949	16,539	232	2,752
Pensacola, Fla	650	4,284						
Mobile, Ala	6,489	35,049						
All others	108	3,999	162	3,429	114	4,471	469	12,519
	257,033	1,952,407	221,260	1,696,043	209,021	1,793,143	178,203	1,350,223

WORLD'S PRODUCTION OF ORE.

The following table gives the latest available statistics with regard to the world's production of manganese ore. The unit is either the long or the metric ton, except for Canada, where the short ton is used.

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[a] This total duplicates the importation from January 1 to June 30, 1873.

World's production of manganese ores.

Country.	Year.	Quantity.	Country.	Year.	Quantity.
North America:		*Tons.*	Europe—Continued.		*Tons.*
United States	1908	6,144	Portugal	1906	22
Cuba	1907	34,171	Russia	1906	1,016,000
South America:			Spain	1906	63,000
Brazil[a]	1905	233,950	Sweden	1907	4,300
Chile	1905	1,324	Turkey[a]	1905	28,600
Europe:			Norway	1904	22
Austria	1907	16,800	Asia:		
Bosnia and Herzegovina	1906	7,651	India	1906	504,000
Hungary	1906	11,000	Japan	1906	13,000
France	1907	18,200	Java	1905	1,600
Germany	1907	75,000	Oceania:		
Greece	1906	10,000	Queensland	1906	1,130
Italy	1907	3,700	New Zealand	1906	16
United Kingdom	1907	16,400			

[a] Exports.

FERROMANGANESE AND SPIEGELEISEN.

PRODUCTION.

The manufacture of spiegeleisen in the United States began in 1870[a] from the manganiferous zinc residuum of zinc-oxide works, using New Jersey manganiferous zinc ores. This production has continued and has increased yearly up to the present. About 1875 manganiferous iron ores were first used in this country in the manufacture of iron-manganese alloys at the Woodstock furnaces[b] at Anniston, Calhoun County, Ala. Soon after this a considerable portion of the domestic production of manganese and manganiferous iron ores began yearly to go into the manufacture of the iron alloys. During late years, however, the proportion of domestic ore used for this purpose has decreased materially and at present most of it is being consumed in the coloring of brick and pottery. The imported manganese ore, however, is used largely in the manufacture of spiegeleisen and ferromanganese, though considerable quantities are being consumed in the manufacture of dry cells.

Manganiferous silver ores were not used in the manufacture of iron-manganese alloys until about 1886 or 1887, but since then there has been a steady though small production from this quarter.

By far the larger part of the iron-manganese alloys are at present produced in Pennsylvania, but small quantities are produced in New Jersey, Maryland, Illinois, and Colorado. The New Jersey product is manufactured from manganiferous zinc residuum and the Colorado product largely from manganiferous silver ores.

The production of ferromanganese and spiegeleisen in the United States has been recorded since 1872, there being no record of the product for the two years previous. In general there has been a steady increase in production from 4,072 tons in 1872 to 339,348 tons in 1907, although in a number of years the production has fallen behind the previous years. The production during 1908 amounted to only 152,018 long tons.

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[a] Penrose, R. A. F., jr., op. cit., p. 27.

[b] Weeks, J. D., Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 400.

The following table gives the total quantity of spiegeleisen and ferromanganese produced in the United States as far as it has been recorded:

Production of spiegeleisen and ferromanganese in the United States, 1872–1908, in long tons.

1872	4,072	1892	179,131
1873	3,930	1893	81,118
1874	4,070	1894	120,180
1875	6,993	1895	171,724
1876	5,907	1896	131,940
1877	7,897	1897	173,695
1878	9,530	1898	213,769
1879	12,438	1899	219,768
1880	17,503	1900	255,977
1881	18,827	1901	291,461
1882	19,610	1902	212,934
1883	21,941	1903	192,661
1884	30,262	1904	219,446
1885	30,956	1905	289,983
1886	42,841	1906	300,500
1887	42,498	1907	339,348
1888	48,901	1908	152,018
1889	76,628		
1890	133,180		4,211,403
1891	127,766		

PRICES.

The prices of iron-manganese alloys vary with the content of these metals. However, as the alloys are generally made with a fairly definite composition, the prices vary only within small limits.

The following table shows the average range of prices for various iron-manganese alloys during 1908.

Prices per long ton of iron-manganese during 1908.

Ferromanganese[a]	$44–$48
Spiegeleisen[a]	30– 34
Silicomanganese	90–125
Silicospiegel[a]	33– 41

IMPORTATION.

Before 1870 all the ferromanganese and spiegeleisen used in the steel industry in this country was imported from Europe, amounting to a maximum yearly importation of about 25,000 tons.[b] During the early seventies the imports amounted to 20,000 or 30,000 tons yearly, but they rapidly increased until during the fiscal year 1884, the first year of which we have a definite record, the imported product was 94,210 tons. Since then the amounts imported yearly have been variable, ranging from 8,127 tons in the fiscal year 1895 as a minimum to 176,966 in 1907 as a maximum. On the whole, however, there has been a great increase in the quantity of imports.

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[a] Compiled from weekly tables in the Industrial World, Pittsburg.

[b] Penrose, R. A. F., jr., op. cit., p. 29.

The following table gives the quantity of ferromanganese and spiegeleisen imported into the United States, by fiscal years, as far as has been recorded:

Imports of ferromanganese and spiegeleisen into the United States during fiscal years ending June 30, 1884–1908, in long tons.[a]

Year ending June 30—	Ferro-manganese.	Spiegel-eisen.	Total.
1884	94,210		94,210
1885	65,406		65,406
1886	99,426		99,426
1887	150,205		150,205
1888	108,973		108,973
1889	93,032		93,032
1890	108,771		108,771
1891	54,239		54,239
1892	55,080		55,080
1893	49,157		49,157
1894	11,579		11,579
1895	8,127		8,127
1896	66,608		66,608
1897	11,301		11,301
1898	6,346	10,108	16,454
1899	10,392	3,615	14,007
1900	10,684	13,675	24,359
1901	8,995	16,308	25,303
1902	37,618	31,416	69,034
1903	53,121	122,566	175,687
1904	23,903	50,620	74,523
1905	41,166	22,443	63,609
1906	62,064	88,224	150,288
1907	94,543	82,423	176,966
1908	58,101	18,504	76,605
Total			1,842,949

[a] Imports prior to 1884 not recorded. Estimated tonnage imported yearly during the seventies is about 20,000 to 30,000 tons.

The following table gives the importation of spiegeleisen and ferromanganese into the United States from 1903 to 1907, by calendar years:

Ferromanganese and spiegeleisen imported and entered for consumption, 1903–1908, in long tons.

Year.	Ferromanganese.		Spiegeleisen.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
1903	41,519	$1,699,666	122,015	$2,709,317	163,534	$4,408,983
1904	21,813	707,037	4,623	132,461	26,436	839,498
1905	52,841	1,884,651	55,457	1,336,104	108,298	3,220,755
1906	84,359	4,953,644	103,268	2,942,940	187,627	7,896,584
1907	87,400	5,354,656	48,994	1,399,381	136,394	6,754,037
1908	44,624	1,860,664	4,579	125,054	49,203	1,985,718

CHAPTER VII.

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THE
PURCHASE OF COAL BY THE GOVERNMENT UNDER SPECIFICATIONS

WITH ANALYSES OF COAL DELIVERED FOR THE FISCAL YEAR 1908-9

BY

GEORGE S. POPE

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THE PURCHASE OF COAL BY THE GOVERNMENT UNDER SPECIFICATIONS.

By George S. Pope.

INTRODUCTION.

SCOPE AND OBJECTS.

This bulletin is the third of a series [a] showing the results of government purchases of coal according to specifications as to its quality and giving typical forms of proposals for supplying coal and general information relating to government coal purchases.

Numerous calls for authentic information concerning the purchase of coal according to its heat value attest a growing interest in the subject. Many of the commodities of life have long been purchased according to specifications requiring chemical or physical tests, or both, to determine whether the material delivered meets the requirements, the price to be paid depending on the results of the tests.

Until recent years coal consumers purchased coal merely on the statement of the dealer as to its quality, relying on his integrity and on the reputation of the mine or district from which the coal was obtained. It is surprising that the important question whether value was being received for the money expended was not sooner seriously considered.

The purchase of coal by specification is an important step toward the conservation of our national mineral resources, for it results in an increased use of the lower grades of coal. The poorer coals find a market by competing with the better grades, not as to the price per ton but as to the cost of an equal number of heat units.

This paper gives in detail the results of government purchases of coal for the fiscal year 1908–9 and the list of contracts with abstracts of specifications for the fiscal year 1909–10, and summarizes the information on this subject obtained by the Survey. It is hoped that this information will promote a better understanding of the specification method of purchasing coal and furnish data valuable alike to coal dealers and coal consumers, so that equitable contracts can be more readily made.

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[a] Randall, D. T., The purchase of coal under government and commercial specifications on the basis of its heating value, with analyses of coal delivered under government contracts: Bull. U. S. Geol. Survey No. 339, 1908. Burrows, J. S., Results of purchasing coal under government specifications: Bull. U. S. Geol. Survey No. 378, 1909.

PERSONNEL.

The work reported in this bulletin is under the general charge of J. A. Holmes, chief of the technologic branch of the United States Geological Survey, and H. M. Wilson, assistant chief technologist. The section of coal inspection, under the technologic branch, is charged with the duty of ascertaining the quality of coal delivered under specifications. For the fiscal year 1908–9, up to March, 1909, J. S. Burrows had direction of the work of this section. On the resignation of Mr. Burrows in March the writer took charge, with P. M. Riefkin as first assistant and N. H. Snyder, F. J. Simington, A. A. Straub, Leo Loeb, E. W. Miller, W. J. Harris, jr., and H. H. McKee as inspectors and J. W. Peters as expert computer.

VALUE OF COAL AS FUEL.

REQUIREMENTS OF USE.

Coal is now burned for power production in gas producers and in boiler furnaces. For coals and lignites high in moisture or high in ash, the gas producer, used in connection with a gas engine, is best adapted to develop power, but for the generation of steam, which can be used for heating as well as for power, coal may be more conveniently burned in a specially constructed furnace under a boiler.

Coal is burned under boilers for producing power, for drying various materials, or for warming buildings. The most valuable coal, therefore, is that which gives up the most heat to the boiler for a given weight burned.

The value of a coal is indicated by the number of heat units it contains. This heating value is expressed in terms of British thermal units (abbreviated B. t. u.) per pound of coal, and is determined by means of a special apparatus called a calorimeter.

In purchasing coal for any power plant the aim should be to obtain a fuel which, all things considered (such as equipment, price of coal, and cost of labor and repairs), will produce a horsepower for the least cost. Experiments seem to indicate that almost any fuel may be burned with reasonable efficiency in a properly designed apparatus. The recognized requirements are as follows: (1) A uniform and continuous supply of fuel to the furnace; (2) an air supply slightly in excess of the theoretical amount required for complete combustion; (3) a temperature sufficiently high to ignite the gases that are driven off from the fuel; (4) a complete mixture of these gases with the air supplied before they reach a cooling surface, such as the shell or tubes of a boiler.

FACTORS AFFECTING VALUE.

General statement.—Some of the factors that may influence the commercial results obtained in a boiler are cost of the coal as determined by price and heating value, care in firing, design of the furnace and boiler setting, size of grate, formation of excessive amounts of clinker and ash, available draft, and size of the coal.

Moisture.—Coal as mined contains more or less moisture. It is exposed to the air in shipment and may either dry out or be drenched by rain. The moisture in the coal delivered is worthless to the purchaser and really costs him a considerable amount in freight and cartage and in the loss of the heat required for its evaporation in the furnace. If all coal contained the same proportion of moisture, or if the moisture in coal delivered by a given dealer were constant in amount, the purchaser's problem, so far as this factor is concerned, would be simplified.

Under present conditions the moisture is an important element in the valuation of a ton of coal. It is evidently necessary to consider the coal just as it is received in order to determine its value to the consumer, but chemical reports should be made on both "dry coal" and "coal as received." The report on dry coal is convenient for comparing several coals to determine the relation of each element to the others; this report is important because the moisture in the same coal varies from day to day. The dry-coal report is also convenient for comparing the performance of boilers burning the same or similar coals. Of several coals having a similar composition, the one that has the least moisture and the least ash will generate the most steam when burned under a boiler.

Ash.—Earthy matter and other impurities that will not burn are classed as ash. In commercial coals the proportion of ash may range from 4 to 25 per cent. Coals containing small percentages of ash are the most valuable, not only because of their correspondingly higher heating capacity, but because they offer less resistance to the free and uniform distribution of air through the bed of coal in the furnace. The labor and cost of managing the fires and of handling the ashes are also correspondingly less and are items to be considered in the choice of a coal. With the ordinary furnace equipment there may be a considerable loss of efficiency and capacity through a large percentage of ash. With some kinds of equipment it has been found that as the ash increases there is a decided drop in both efficiency and capacity. In some experiments made to determine the influence of excessive amounts of ash, coal containing as high as 40 per cent would generate no steam when fired on a chain grate, and therefore the efficiency and capacity of the plant would be zero.[a] Such coal is not only worthless, but its use involves a direct expense, due to the cost of handling it. Whether the result would be similar with equipment other than a chain grate has not yet been determined. However, coals so high in ash that they are unsuited to boiler furnaces can be utilized in gas producers.

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[a] Abbott, W. L., Some characteristics of coal as affecting performance with steam boilers, a paper read before the Western Society of Engineers, Chicago, Ill.

Volatile matter and fixed carbon.—The volatile part of some coals, shown in the analyses, may be all combustible, but it generally contains some inert matter. The amount of this differs in different coals, and therefore it is impossible to determine the heating value of any coal from its proximate analysis alone. Moreover, different coals that contain the same proportion of volatile matter do not behave alike in the furnace. In order to determine the value of one coal as compared with another for the same purpose it is important to know both the chemical composition and the British thermal units.

Of two coals of different character, the one that contains the higher proportion of fixed carbon is most easily burned, so as to give the maximum efficiency. However, if the coal containing the higher volatile matter is properly burned in a suitably designed furnace it may be made equally efficient.

Sulphur and clinker.—Sulphur may be present in the free state, or, as is more common, in combination with iron or other elements. Other impurities with sulphur often form a clinker that shuts out the air and increases the labor of handling the furnaces. It is possible, however, to burn coals containing up to 5 per cent of sulphur without great difficulty from clinkers. A little steam introduced under the grate will relieve much of the trouble. Clinker may be due to other causes than sulphur, as any constituents of the ash which are easily fusible may produce it. There is need of further investigation to determine the influence of sulphur and the elements that form ash in furnace fires during combustion.

Size of coal.—The size of the coal influences the capacity of any given equipment, owing to its effect on the draft. With a poor draft fine coal can not be burned in sufficient quantities to maintain the rated capacity. If thin fires are resorted to, the efficiency is usually lowered as a result of an excessive supply of air through holes in the fire. As a rule, when dust and very fine coal are fed into the furnace they either check the flow of air or are taken up by the draft and after being only partly burned are deposited back of the bridge wall; or they may pass up the stack, to the annoyance of people in the vicinity of the plant. If this dust is completely burned in passing through the furnace there is of course no loss of fuel. Coal of uniform size forms the most satisfactory fuel, as it does not pack so closely as coal of different sizes mixed.

In general it may be said that in any market the coal obtainable at the lowest price is the most economical, provided the furnace equipment is suitable. If the furnace is not so designed as to permit the use of the cheaper coal it should be changed.

Heat units.—The tests tend to show that, other conditions being equal, coals of similar composition are of value in proportion to the British thermal units, and the determination of these units in any coal will give approximately its value. It should be remembered, however, that the value of a coal for any particular plant is influenced by the character of the furnace, for all furnaces are not equally suitable for burning the many grades of coal. Aside from this factor, coals may be compared in terms of the British thermal units obtained for 1 cent, or on the cost per million heat units.

Summary.—In the purchase of coal, then, attention should be given to the character of the furnace equipment and the load, the character of coal best suited to the plant conditions, the number of heat units obtainable for a unit price, the cost of handling the coal and ash, and the possibility of burning the coal without smoke or other objectionable features.

GENERAL PLAN FOR COAL PURCHASES UNDER SPECIFICATIONS.

HISTORICAL STATEMENT.

Until the last few years little information has been available regarding the coals and the coal supply of the United States. Until such information was obtained the heat-value method of purchase could not be used, because its use requires a knowledge of the chemical and physical properties of the coals, indicating their calorific value as well as their behavior when being consumed.

The lack of such information was recognized in the establishment of the fuel-testing plant of the United States Geological Survey at St. Louis on the grounds of the Louisiana Purchase Exposition, in 1904. Extended general investigations and a comprehensive study of the practical utilization of the coals have been made in this plant and its successors and in the coal fields. Similar investigations are now being made in Pittsburg, Pa. As a result of these investigations authentic information of great practical value has been made available for the government departments as well as the public, and it has been possible to establish the present rational method of purchasing a large part of the Government's coal supply.

A few years before the present system of coal buying was adopted the necessity for a uniform standard became apparent in some of the government departments, and the plan of purchasing coal according to its heat value was introduced. It proved successful, especially in the Treasury Department, under which coal is bought for post-offices and other public buildings throughout the United States.

This work led to the development of general and uniform specifications for purchasing the government fuel supply. In an act making appropriations for sundry civil expenses for the fiscal year 1907, Congress recognized the importance of supervising more carefully the Government's coal purchases and charged the Geological Survey with the work of testing coal for government use. As a result of this legislation a form of specifications was drafted by engineers in the employ of the Government and in March, 1907, was approved by the national advisory board on fuels and structural materials. Contracts based on these specifications went into effect July 1, 1907. Before an attempt was made to draft this form of specifications, the general fuel-testing investigations carried on at St. Louis, Mo., were supplemented by analyses and tests of a large number of samples of coal being delivered under contracts to buildings in Washington and elsewhere, and this work formed the basis for the standards set in the specifications. The same general form of specifications, modified by changes made as the result of their practical application, has since been in use.

ADVANTAGES OF DEFINITE SPECIFICATIONS.

Defects of the old plan.—Under the old plan of purchasing coal, when the consumer had cause or thought he had cause to find fault with the quality of the fuel he received, he was assured that it must be good because, like all the other coal sent him, it came from a mine with an established reputation. Such a state of affairs made it difficult to take advantage of the competition which usually results when a considerable number of bidders are asked to submit prices. The purchaser was afraid to buy from any dealers but those he knew and trusted, because, although each dealer claimed that his coal was equal in quality to that of the others, yet if it did not prove to be satisfactory there was no standard for settlement or for cancellation of the contract. Many thousands of dollars worth of coal is bought each year in this manner, yet a buyer or investor would consider it absurd to make a contract for a building with no specifications other than that it should be of a certain size and well constructed. Neither would he buy gold, silver, or even copper and iron ores on the mere information that they were mined at certain localities. All products of mines are now purchased to a great extent according to their value as shown by chemical analysis. This is true of coal in only a small degree, but the number of coal contracts made on this basis is increasing every year.

The purchase of coal under specifications is as advantageous as a definite understanding regarding the quality and other features of any other product, or of a building operation or engineering project. The man who buys under specifications gets what he pays for and pays for what he gets.

Standard of quality.—When the bidder is allowed to specify the quality of the coal he proposes to furnish, as determined by chemical analysis, he is placed on a strictly competitive basis with other bidders. Such a procedure broadens the field for both the bidder and the purchaser. It makes the bidder's proposal, when accepted, a contract that specifies an established standard of quality. This furnishes a basis for settling disputes regarding the quality of the coal delivered and the price to be paid if the fuel is either better or poorer than has been guaranteed. If other coal must be substituted, as often happens, there is a standard for settlement. If the coal is uniformly poorer than the standard as specified there is a basis for cancellation of the contract.

The quality of coal from a given mine may vary from time to time through the failure of the miners to reject impurities; or the physical and chemical character of the coal of a certain bed may vary from place to place. In some coal fields different beds of coal are mined at the same time and the output is mixed. When there is need of preparation, as by picking slate and other impurities, or jigging or washing, the quality or value of the coal marketed depends a great deal on the care taken in the processes employed. The mining companies are responsible in a large measure for variations in the grade of prepared coal. The purchase of coal under a contract that distinctly specifies its quality stimulates the operator to prepare coal better before shipping it to market. Examples of fluctuation in quality are furnished by the table on pages 47–76, which show variations both in ash and in British thermal units of coal delivered.

Nature of specifications.—Government specifications are drawn with a view to the consideration of price and quality. For manufactured articles and materials of constant and uniform quality they generally can be reduced to a clear and simple statement of what is desired, but for coal, which may be considered a finished product when loaded on the railroad cars at the mine, the great and obscure variation in character makes a simple requirement impracticable, and this fact is recognized and provided for in the coal specifications prepared by the Geological Survey. Under these specifications bidders are requested to quote prices on the various sizes of anthracite, a definite standard of quality being specified for each size, and to state the standard of quality and price for bituminous coal. Awards are then made to the lowest responsible bidder for anthracite and to the bidder offering the best bituminous coal for the lowest price, the amount finally paid being determined by the tests made under the terms of the specifications. The specifications become part of the contract, and payment for coal delivered is made according to the standard of quality fixed. The actual quality and value of coal delivered is determined by analysis and test of representative samples taken in a specified manner by agents of the Government and analyzed in the government fuel-testing laboratory at Washington. For coal of better quality than the standard the contractor is paid a bonus proportional to its excess of value. For coal of poorer quality than the standard, deductions are made from the contract price proportional to its deficiency in value.

It evidently will not be satisfactory to either the buyer or the seller to establish a standard for the coal unless the liability to variation is recognized and provision made for settlement when the coal is better or poorer than the standard. Experience with any method of buying coal shows that it will seldom be rejected when of poor quality, because of the difficulty, delay, and cost of removing it from the bins. The buyer is often confronted with the alternative of burning the coal delivered or going without fuel until more can be procured. Unless the coal is very bad it is usually expedient to use it and pay a smaller price. This is also more favorable to the contractor, as to remove the coal would be costly and it would not be satisfactory as fuel to any other customer.

Summary of advantages.—The advantages of purchasing coal under specifications may be briefly summarized as follows:

(1) Bidders are placed on a strictly competitive basis as regards quality as well as price. This simplifies the selection of the most desirable bid and minimizes controversy and criticism in making awards.

(2) The field for both the Government and dealers is broadened, as trade names are ignored and comparatively unknown coals offered by responsible bidders may be accepted without detriment to the Government.

(3) The Government is insured against the delivery of poor and dirty coal, and is saved from disputes arising from condemnation based on the usual visual inspection.

(4) Experience with the old form of government contract shows that it is not always expedient to reject poor coal, because of the difficulty, delay, and cost of removal. Under the present system rejectable coal may be accepted at a greatly reduced price.

(5) A definite basis for the cancellation of contract is provided.

(6) The constant inspection and analysis of the coal delivered furnishes a check on the practical results obtained in burning the coal.

GROWTH OF THE SYSTEM.

Contracts for the fiscal year 1908–9 under which the United States Geological Survey was called upon to make tests and analyses covered 611,362 tons, at an estimated cost of $1,858,750; those for the fiscal year 1909–10 covered 829,289 tons, at an estimated cost of $2,286,800.

A few government stations have their own laboratories for analyzing and testing coal delivered under specifications. The number of tons and cost covered by these contracts would somewhat increase the quantities and values above given.

METHODS OF SAMPLING AND TESTING.

MINE AND CAR SAMPLES.

Comparative study.—In connection with the study of the coal deposits of the country and the best methods to prevent waste in mining and utilizing the coal supply, trained inspectors of the United States Geological Survey have visited about a thousand mines in all of the coal-producing States and Territories, taking two or more samples from each mine. A study of the analyses of these samples and of samples taken from cars shipped from more than 200 mines shows that the mine samples are as a rule better than the average coal shipped in cars. The average coal delivered contains about one-third more ash than the mine sample. This difference is due to the fact that the trained government inspector is able to free most of the small mine samples more completely of bone, slate, and other extraneous matter than the miner, who endeavors to get the maximum number of tons past the tipple inspection, the nature of which is presumably determined by trade and market conditions. Most of the samples collected by the government inspectors from the mines show a higher moisture content than the commercial samples, because of the precaution taken by the inspectors to prevent loss of moisture in the collection, preparation, and analysis of the mine sample.

When properly taken, mine samples indicate the general character of the coal and enable one to determine its probable value for any designated purpose.

Samples taken from railroad cars should not be limited to a few shovelfuls of coal procured from the top of the car, for the quality of the coal may not be the same throughout the car; indeed, it is sometimes found that the heavier pieces have gradually shifted in transit toward the bottom. Tests of samples taken at the bottom of a car have shown as much as 8 per cent more ash than samples taken at the top. The moisture content also may vary from top to bottom, depending on the weather. The only way to get a fair sample is to take a number of shovelfuls of coal from different points in the car when the coal is unloaded, so as to procure a representative portion of the coal from top to bottom and from end to end.

Weight of sample.—The number of pounds to be taken as a fair sample of a given lot of coal varies according to the size, character, and condition of the coal and depends also upon the character and amount of the extraneous matter as well as on the size of the particles of both coal and impurities. It is therefore evident that the sampling should not be left to an inexperienced person, but should be done by one who is thoroughly familiar with the significance of the factors just stated and who has some intimate knowledge of the coal to be sampled.

MOISTURE CONTENT OF THE COAL.

Adjustment of price to weight.—Bituminous coal when exposed to the air gradually depreciates in heating value, owing to loss of volatile matter, but aside from this loss a car of coal should represent the same total number of heat units when it reaches its destination as when it started. If rain falls on the coal it will become heavier and a greater number of pounds will be delivered, but each pound will have a correspondingly lower heat value. On the other hand, if the weather is fair and the coal dries out on the way, it will weigh less and the heating value of each pound will be correspondingly higher. In other words, under specifications such as are used by the Government, neither the dealer nor the purchaser will gain or lose by change in the moisture content of the coal between the time it is weighed at the mine and the time it is weighed on delivery. The price per ton will be correspondingly lower if the coal is wet and higher if the coal is dry.

Practical considerations.—The number of heat units per pound of coal "as received" varies in inverse proportion to the variation in its content of moisture, so that for a correct determination of the price to be paid for the coal it is important that the sample analyzed should contain the same percentage of moisture that existed in the coal delivered. It is physically impossible to preserve the same actual amount of moisture in the sample, for in being prepared for the laboratory it is exposed to conditions that tend to vary its content of moisture. The crushing and quartering of the original sample exposes a greater surface to the action of the air, so that even under the most satisfactory conditions it is probable that the percentage of moisture in the sample will be less than the percentage of moisture in the coal weighed at the point of delivery.

This variation favors the coal dealer, for a decrease in the moisture content of the sample below the moisture in the coal delivered represents so much gain in heating value, which increases the price he will receive for the coal.

In coals in which the difference between the moisture in a carload and the percentage of moisture in the air-dried sample is relatively small, and in coals that are easily and quickly sampled and worked down to a laboratory sample, this error is so small that it is practically negligible. It is with coals in which the moisture difference from time to time is relatively large that trouble is experienced, for it is difficult to determine exactly the amount of moisture in these coals as weighed for delivery.

It is therefore evident that a careful and uniform method of sampling coal and preparing and analyzing samples should be followed in order that the variations in moisture may be reduced to a minimum.

The moisture in an air-dried sample is that remaining after the coal has been reduced to a prescribed size and has been exposed to a prescribed temperature or to specified conditions for a stated period of time. The air-dried condition is virtually a "moisture-balanced" one, depending on the temperature, humidity, and barometric pressure in the laboratory. The percentage of moisture in the air-dried sample is a function of the physical and chemical character of the coal. The minimum percentage is found in anthracite and semibituminous coals, and the proportion increases as the grade of coal decreases, becoming higher and higher in bituminous, subbituminous, and lignite.

Samples of coal that is purchased "as received" should not be taken from coal in the boiler room, for this coal has been exposed to relatively high temperatures; neither should samples be stored in the boiler room, as they will inevitably lose moisture and such loss may materially affect the price paid for wet coals. The drier the coal that is fed to the furnace the greater the evaporation per pound of coal, for less heat is required to evaporate the water in dry coal, but this is a matter of efficiency of plant and not of economy of purchase, though the two are often confused.

PROCEDURE IN PRACTICE.

IN WASHINGTON.

Gathering samples.—Whenever a delivery of coal is to be made at one of the department buildings in Washington an inspector is sent to remain during the unloading of the coal. This inspector is provided with galvanized-iron buckets, each large enough to hold about 65 pounds of coal and equipped with closely-fitting lid and lock. In these buckets portions of coal taken from every part of the lot delivered are placed, care being taken that the samples shall truly represent the coal delivered. These samples are secured by locking the buckets, which are immediately delivered to the crushing or sampling room in the United States Geological Survey building.

Preparation of samples.—Machinery for preparing the collected samples is installed in the crushing room. The large samples, weighing 65 to 200 pounds (the weight depending on the character of the coal and the amount delivered), are put through a motor-driven baby hammer crusher, which has a capacity of about 1 ton of furnace anthracite coal per hour. This machine crushes the coal to a size that will pass through a ¼-inch mesh. An arrangement of automatic riffles mechanically quarters the crushed coal. The quarter thus separated is then put through a portable mechanical sampler or riffle and reduced to a portion weighing 2 pounds, and is then hermetically sealed in a 3 by 9 inch cylindrical can bearing the number of the gross sample.

If the coal of the 2-pound sample will not pass through a ¼-inch mesh—and the coal of some samples taken outside of Washington will not—it is reduced to the proper fineness by means of an adjustable chipmunk jaw crusher.

The 2-pound sample is next reduced to 20-mesh fineness in a roll crusher and a 2-ounce portion is segregated and placed in a rubber-stoppered bottle preparatory to determining its content of moisture. The 20-mesh coal is then thoroughly mixed, after which it is passed through riffles and reduced in quantity to about 2 ounces. This 2-ounce sample is further reduced in fineness on a bucking board until all its particles will pass through a 60-mesh screen. It is then placed in a rubber-stoppered bottle and sent to the laboratory for analysis. During this process of reduction the sample has unavoidably become partially air dried, but accuracy in calculation to its condition "as received" is insured by using for this purpose the segregated 2-ounce portion referred to above.

Removal of dust.—Much objectionable dust is produced during the process of crushing. To prevent this dust from escaping to circulate about the building the wooden partitions and doors of the crushing room are covered with sheet iron, a system of hoods and pipes collects and carries the dust-laden air to the main furnace stack of the building, and a fan draws fresh air into the room.

Laboratory treatment.—On its receipt each sample is numbered and the record identifies this new number with the serial numbers that the sample has borne at each stage of its earlier history. The method of analysis is that adopted by the American Chemical Society. The calorific value is determined with a bomb calorimeter. The results of the analysis are reported to the coal-inspection section for use in the public service.

OUTSIDE OF WASHINGTON.

Samples of coal delivered to points outside of Washington are taken in accordance with instructions furnished by representatives of the department for which the coal is purchased. With few exceptions the samples are crushed by hand, prepared, and reduced to quantities weighing about 2 pounds. Each sample is placed in a cylindrical galvanized-iron can 9 inches in length and 3 inches in diameter, with a screw cap 2 inches in diameter. This can is immediately sealed air-tight by wrapping several turns of electrician's adhesive tape around the connection of the cap and can. A wrapper bearing marks of identification is put on the can and it is sent by mail or express to the coal-inspection section of the United States Geological Survey, at Washington, for analysis of the sample. Detailed information to be placed on record is sent under a separate cover for the identification of the sample.

GENERAL DIRECTIONS FOR SAMPLING.

Need of experience and caution.—Persons who have had no experience in taking samples are liable to select a sample better than the average run of the coal. Occasionally a lump of coal is broken and shipped to the laboratory in a cloth sack, which allows the moisture to dry out; moreover, the lump selected is usually free from layers of slate and impurities, and of course then represents the best coal in the lot rather than the average, and its analysis will show a higher value than the coal delivered. Especial care should be exercised to note the proportion of slate and other foreign substances, in order that such impurities may be included in the sample in the same proportion. Experience and good judgment on the part of the sampler are necessary to insure the collection of a representative sample; and it is well to remember that as the larger lumps of coal roll down and collect near the bottom of a pile or load a sample taken entirely from near the floor would not fairly represent the whole.

Loss of moisture in samples.—In spite of every precaution taken to prevent loss of moisture during the collection, preparation, and analyses of samples, it is certain that loss of moisture may occur, whereby the heat value of the coal as shown by analysis of the sample is greater than that of the coal from which the sample was taken. It is important to the purchaser and fair to the dealer that the quality should be determined on the coal "as received." In the interest of equity, therefore, the suggestions that follow are presented for the guidance of those who wish to send samples to a laboratory for analysis.

Wagonload deliveries.—Samples taken from coal delivered at a department building should consist of a shovelful of coal taken from each wagonload or from each third or fifth load, the number of samples taken depending on the loads delivered. It is important to obtain representative portions of coal from every part of the delivery, so that the samples will show the quality of the delivery or order as a whole. The sample should contain about the same proportion of lump and fine coal that is contained in the coal as delivered.

If the quantity delivered is 100 tons or more, at least two samples should be taken, one representing the earlier and the other the later delivery. The average of two or more analyses will represent more accurately the quality of the coal than a single analysis, because it is difficult to preserve the character of the large sample in reducing it to the small sample required for laboratory use.

Cargo deliveries.—In determining definitely the number of samples to be taken to represent different quantities delivered many variable factors must be considered. For cargoes of 4,000 to 6,000 tons the approved method is to take a sample of about 65 pounds from every third railroad car when unloaded; three such samples, representing nine cars, are mixed and reduced by quartering to the regular 2-pound sample. By this procedure 8 to 14 samples are obtained for the cargo. An analysis representing the whole cargo is obtained by averaging the results of analyses. It is impracticable to take a single large sample to be fairly representative and reduce it to a 2-pound sample for laboratory treatment, for the analysis of a single sample would probably not correctly represent the quality of the whole of a large cargo.

Stowage and quartering down.—A gross sample should, when taken, be immediately placed in a metal receptacle having a tight-fitting cover and a first-class lock, and when samples are being quartered down each receptacle should be securely locked and the key held by a responsible employee. The receptacle should be placed in a comparatively cool place to minimize loss of moisture from the sample; and for the same reason the process of quartering down and preparing samples for shipment to the chemical laboratory should be carried on as rapidly as possible. This process, briefly described, is as follows:

The contents of the receptacle or receptacles are emptied in a clean, dry space, preferably on a sheet-iron plate of suitable dimensions, so located as to prevent admixture of foreign matter with the sample during its preparation. All the lumps are then broken by a maul or sledge until they will pass through a half-inch mesh. The mass is then thoroughly mixed, formed in a conical pile, and equally quartered by means of a shovel or board. Two opposite sections are next rejected and the remaining sections are mixed. The pile is then reformed and opposite quarters are discarded as before. This process is continued until only about 2 pounds remain. This final sample is immediately placed in a suitable receptacle for shipping and is sealed air tight. The metal can in use by the United States Geological Survey for this purpose is 9 inches high and 3 inches in diameter.

Shipment.—The 2-pound samples thus prepared should be forwarded promptly and notice of shipment sent under separate cover. Receptacles should be marked plainly on the outside and a corresponding number or description should be placed inside. A complete record of all deliveries should be kept, showing dates, names of contractor, kind of coal, total weight delivered, condition of coal (wet or dry), and any other important details.

THE GOVERNMENT AS A COAL CONSUMER.

EXTENT OF GOVERNMENT PURCHASES.

The United States Government purchases annually from $6,500,000 to $7,000,000 worth of fuel. This sum includes the cost of delivery and of stowage. Each department buys coal through its purchasing officers. The Navy, War, Treasury, Interior, and Commerce and Labor departments are large consumers of coal. Much of the coal used by the Government must be delivered by wagon, and the business is therefore limited to dealers having hauling facilities. This is especially the case in the city of Washington, where coal is purchased principally for heating the public buildings.

The Treasury Department is a large consumer of coal delivered in wagons, for the fuel required for post-offices, custom-houses, United States court-houses, marine hospitals, mints, and other federal buildings throughout the country is purchased by this department, which also buys for the Revenue-Cutter Service.

The Navy Department is a large car-lot consumer as well as a purchaser of large cargoes of coal for foreign delivery. The Bureau of Supplies and Accounts of this department purchases the larger quantities for the ships of the navy and the car lots for use in the navy-yards.

The War Department makes purchases of coal for the many forts and army posts in the United States and foreign possessions and for the ships in the army transport service. The car-lot consumers are the Ordnance Department, which buys coal for the arsenals, and the Engineer Corps, which buys fuel for use in river and harbor improvement and other construction work.

Coal for use in the Canal Zone, Isthmus of Panama, is purchased by the Panama Railway Company of New York f. o. b. at an Atlantic port in the United States, being shipped at present from Norfolk, Va.

The Department of Commerce and Labor purchases coal for the vessels of the Coast and Goedetic Survey and for the Immigration Service. At the Ellis Island immigration station, New York, 10,000 tons, mostly bituminous coal, is bought annually. Fuel for the light-houses is purchased by this department, the service being divided into sixteen districts, for each of which a separate contract is made. Each of these contracts covers 1,000 to 13,000 tons and calls for anthracite or bituminous coal. The Bureau of Fisheries is a consumer of anthracite and bituminous coal in small lots, delivered to the cars of the bureau and to its stations throughout the country.

The Interior Department is a large consumer of coal in Washington, where it purchases annually 20,000 tons of bituminous and 1,000 tons of anthracite coal for the Government Hospital for the

Insane. Outside of Washington this department's most important contracts are those for coal to be delivered to Indian schools and agencies.

Most of the coal purchased by the Government is used for warming public buildings and for generating power, though small quantities of blacksmith's or forge coal and coke are bought. The larger individual contracts are those for bituminous coal and the small sizes of anthracite. The larger sizes of anthracite are, as a rule, purchased in small lots and delivered mainly by wagons.

PRACTICE IN THE TREASURY DEPARTMENT.

AWARD OF CONTRACTS.

COMPARISON OF HEATING VALUES.

An important point which seems not to be thoroughly understood is the manner of making awards in purchasing coal according to its heating value. In order to show how the lowest bid is determined, the proposals for supplying coal to the federal buildings under the Treasury Department have been selected as representing the widest range of coals and conditions throughout the country.

All bids are received on official proposal blanks, in sealed envelopes, in response to advertisements inserted in the daily papers. These bids are opened at a specified time, in the presence of all who desire to attend, and awards are made as soon thereafter as possible.

In order to make a proper award of contract it is necessary to reduce the proposals to a common basis for comparison. This may be done in several ways, but the method chosen is to adjust all bids on a given lot of coal to the same ash percentage by selecting as the standard the proposal that offers the coal containing the lowest percentage of ash. Each 1 per cent of ash content above that of this standard is assumed to have a negative value of 2 cents a ton, the amount of the penalty which is exacted under the contract requirements for 1 per cent excess of ash. The proposal prices are all adjusted in this manner and are so tabulated. On the basis of the adjusted price, allowance is then made for the varying heat values by computing the cost of 1,000,000 British thermal units for each coal offered. In this way the three variables—calorific value, percentage of ash, and basic price per ton—are all merged into one figure, the cost of 1,000,000 British thermal units, by which one bid may be readily compared with another.

For example, take two bids received for coal in Boston, as follows:

TABLE 1.—*Bids showing price computations based on determined ash and calorific values.*

Bid.	Coal offered.	Determinations.		Price per ton (2,240 pounds).		Computed cost of 1,000,000 B. t. u.
		B. t. u. per pound.	Ash (per cent).	As bid.	Plus ash difference.	
1	2	3	4	5	6	7
E	Raleigh County, W. Va........................	14,327	5.91	$4.19	$4.19	$0.13056
B	Cambria County, Pa..............................	14,200	7.12	4.30	4.3242	.13595

The percentage of ash (column 4) in E is taken as a standard of comparison, and the determined ash in B is shown to be 1.21 per cent higher. Each 1 per cent of ash difference from the contract standard is so rated as to make 2 cents difference in the price per ton; 1.21 per cent of ash is valued at $0.02 × 1.21, or $0.0242; bid B is therefore increased to $4.3242 per ton (column 6). The two bids are then on an equivalent basis, so far as ash is concerned.

The heating values being different, it is desirable to compute the calorific cost by the formula:

$$\frac{1{,}000{,}000 \times \text{price per ton}}{2{,}240 \times \text{B. t. u.}} = \text{cost per } 1{,}000{,}000 \text{ B. t. u.}$$

This computation shows the cost of 1,000,000 B. t. u. to be—

In the case of E—

$$\frac{1{,}000{,}000 \times \$4.19}{2{,}240 \times 14{,}327} = \$0.13056.$$

In the case of B—

$$\frac{1{,}000{,}000 \times \$4.3242}{2{,}240 \times 14{,}200} = \$0.13595.$$

In like manner the cost of 1,000,000 British thermal units is calculated for each bid received under the proposal, and the results are entered for ready comparison in column 7 of the table.

The necessity for having such a basis of comparison is evident from an examination of the bids for coal to be delivered on any of the contracts. For instance, in Chicago nine bids were received with guaranties of British thermal units from 11,094 to 14,800, and of ash from 6 to 10 per cent, while the prices ranged from $2.80 to $4.10. Notwithstanding these apparent discrepancies, the cost of 1,000,000 British thermal units ranged only from 11.328 to 12.657 cents.

It has been found desirable to award some contracts to bidders other than those naming the lowest price per ton. Should two or more proposals appear equally advantageous, the relative suitability of the coals for use with the plant to be supplied with fuel may be determined by actual trial tests. An examination of the table on pages 23–32 should dispel any doubt as to the general applicability of the specifications to a wide range of coals delivered in different localities under varying conditions. This table shows the results of analyses of coals mined in ten States—Pennsylvania, Maryland, West Virginia, Illinois, Kentucky, Tennessee, Alabama, Kansas, Virginia, and Colorado—and includes small sizes of anthracite and low and high volatile bituminous and semibituminous coal.

Coals from Pennsylvania, Kentucky, Virginia, and Tennessee compete in Louisville; from West Virginia, Virginia, and Pennsylvania in Toledo; from Illinois, Kentucky, Pennsylvania, and West Virginia in Minneapolis, etc., and fall within the specification limits especially fixed in each city.

OTHER FACTORS.

While calorific rating allows an award to be made to the best economic advantage, other factors than the mere theoretical heating value of the coal may, under certain conditions, have considerable weight, especially where uncertainty exists as to the suitability or adaptability of an untried coal to the plant for which it is purchased, and the consideration of this question must take into account the conditions of furnaces, grates, and draft, the labor of handling coal and ash, the storage facilities, etc.

In plants where boiler capacity and grate area are small or draft is weak, only the best grades of coal can be burned, and it is therefore desirable to take bids for coal to be used in such plants on a general specification, so as to determine the result of making radical changes in the plant to take advantage of the coal that will give the best economic results.

The relative facilities, competency, and responsibility of the competing firms must, of course, also be considered in making awards.

PROPOSALS FOR THE FISCAL YEAR 1909–10.

Table 2 embodies a summary of the Treasury Department proposals, showing the place of delivery, amount to be supplied, character of coal desired, and maximum limits of ash, volatile matter, and sulphur, all as specified by the Government, together with data furnished by the bidders as to the commercial name of the coal offered, name and location of the mine, designation of coal bed, sizing or screening dimensions, guaranteed British thermal units in the coal as delivered, and percentage of ash in dry coal.

TABLE 2.—*Schedule of proposals for coal, United States Treasury Department, fiscal year 1909–10.*

City.	Tons of 2,240 pounds.	Kind of coal (bituminous, except as otherwise stated).	Specified limits (per cent in "dry coal").			Bidder.	Commercial designation of coal.	Mine and location.	Coal bed.	Screen (dimensions in inches).		Heating value of coal "as received" (B. t. u.).	Ash in "dry coal" (per cent).	Price per ton.		Cost, in cents, per 1,000,000 B. t. u.	
			Ash.	Volatile matter.	Sulphur.					Through.	Over.			Bid.	Plus ash difference.	Comparative.	Actual.
Albany (court-house and post-office).	250	Coking; run of mine.	8	22	1.5	A	Luzerne	Young township, Indiana County, Pa.				13,000	8.00	$3.60	$3.60	12.362	......
						B	Clearfield	Portage, Pa.				14,000	8.00	3.44	[a] 3.44	10.969	10.969
	250	Anthracite screenings.	18	9	1	A	Lackawanna birdseye.	Scranton, Pa.				10,500	18.00	2.60	2.62	11.139	......
						C	Lackawanna	do				12,000	17.00	2.40	[a] 2.40	8.928.	8.928
Baltimore...... Court-house and post-office, 2,250 tons; custom-house, 300 tons; appraiser's stores, 100 tons.	2,650	Coking, run of mine.	8	22	1.5	A	Tyson	Elk Garden, W. Va.	Tyson	Run of mine.		14,000	6.40	3.13	3.148	9.967	......
						B	Nanty Glo	Cambria County, Pa.	B	do		14,400	6.50	3.16	3.18	9.858	......
						C	Cambria County steam.	Lincoln, Springfield, and Commercial mines, Vintondale, Cambria County, Pa.	B	do		14,300	6.50	3.16	3.18	9.927	......
						D	Jenner	Somerset County, Pa.	C′	do		14,300	6.50	3.18	3.20	9.990	......
						E	Orenda	Boswell, Somerset County, Pa.	C′			14,350	6.25	3.13	3.145	9.784	......
						F	Logan No. 5	Carrollton, Cambria County, Pa.	B			14,300	8.00	3.25	3.30	10.302	......
						G	Stineman	South Fork, Cambria County, Pa.	B			14,300	7.00	3.40	3.43	10.708	......
						H	Sugarloaf	Mines Nos. 2 and 3, Twin Rocks, Cambria County, Pa.	B			14,400	5.50	3.13	[a] 3.13	9.703	9.703
Custom-house.	500	Anthracite screenings.	18	9	1	I		Mammoth mine, Schuylkill region, Pa.	Mammoth			11,700	18.00	2.35	2.39	9.119	......
						B	Wyoming	Black Diamond mine, Wilkes-Barre, Pa.				12,000	18.00	3.09	3.13	11.644	......
						A						11,500	16.00	2.28	[a] 2.28	8.851	8.851

[a] Standard.

TABLE 2.—*Schedule of proposals for coal, United States Treasury Department, fiscal year 1909–10*—Continued.

City.	Tons of 2,240 pounds.	Kind of coal (bituminous, except as otherwise stated).	Specified limits (per cent in "dry coal").			Bidder.	Commercial designation of coal.	Mine and location.	Coal bed.	Screen (dimensions in inches).		Heating value of coal "as received" (B. t. u.).	Ash in "dry coal" (per cent).	Price per ton.		Cost, in cents, per 1,000,000 B. t. u.	
			Ash.	Volatile matter.	Sulphur.					Through.	Over.			Bid.	Plus ash difference.	Comparative.	Actual.
Boston (post-office and sub-treasury).	1,500	Coking; run of mine.	8	22	1.5	A	Beech Creek Cumberland.	Pardee mine, Cambria County, Pa.	....	......	......	14,129	7.81	$4.33	$4.368	13.801	....
						B	Pardee..........	Patton mine, Patton, Cambria County, Pa.	....	......	......	14,200	7.12	4.30	4.324	13.594	....
						C	Logan..........	Logan No. 1 mine, Adams township, Cambria County, Pa.	....	......	......	14,450	6.50	4.40	4.412	13.630	....
						D	New River......	Fayette, Raleigh County, W. Va.	Sewell......	......	......	14,500	6.00	4.47	4.472	13.768	....
						E	.....do..........	Raleigh County, W. Va.	....	......	......	14,327	5.91	4.19	[a] 4.19	13.056	....
						F	.....do..........	....	....	......	......	14,350	6.00	3.82	3.822	11.890	11.884
	3,000	Anthracite screenings.	18	9	1	A	....	....	....	½	......	11,934	14.15	2.85	[a] 2.85	10.661	....
						F	Philadelphia and Reading.	Lehigh district........	....	......	......	12,650	18.00	2.80	2.877	10.153	9.881
Brooklyn (court-house and post-office).	5,000	No. 2 buckwheat, anthracite.	18	9	1	A	Pittston........	Luzerne County, Pa...	....	......	......	11,150	18.00	3.15	[a] 3.15	12.612	12.612
						B	Scranton and Pittston.	Pennsylvania........	....	......	......	11,300	18.00	3.25	[a] 3.25	12.839	....
						C	Pittston........	Wyoming district.....	....	......	......	11,000	18.00	3.38	[a] 3.38	13.717	....
Buffalo (post-office).	1,000	Coking; run of mine.	9	35	2.5	A	Hillville........	Upper Hillville, Clarion County, Pa.	....	......	......	13,485	7 84	2.90	2.957	9.789	....
						B	Glenova........	Catfish, Pa...........	B........	¾-in. lump		13,791	6.63	2.79	2 823	9.138	....
						C	Reynoldsville...	Reynoldsville mine, Punxsutawney, Pa.	D........	...do......		13,900	6.50	2.90	2.930	9.410	....
						D	Shawmut.......	Shawmut mine, Elk County, Pa.	....	¾	1½	14,100	5.00	2.84	[a] 2.84	8.992	8.992
Chicago (court-house and post-office, 8,000 tons; appraiser's stores, 500 tons).	8,500	Illinois Nos. 1 and 2, washed nut.	10	38	2.5	A	Carterville washed nut.	Centerville district, Williamson County, Ill.	....	3	1½	12,100	9.5	3.08	3.150	11 622	....
						B	Nos. 1 and 2, shellbark.	Peabody No. 3 mine, Marion, Williamson County, Ill.	No. 7........	......	......	11,646	8.6	3.25	3.302	12.657	....
						C	Buckhorn.......	Herrin, Ill...........	....	......	......	11,400	10.00	3.02	3.100	12.140	....
						A	New River......	Nos. 7 and 8 mines, Macdonald, Fayette County, W. Va.	....	......	......	14,800	6.00	4.10	[a] 4.10	12.367	....

						D	Carterville nut	Burr mine, Carterville, Ill.	No. 7	2½	1½	11,680	10.00	3.02	3.10	11.848	
							Majestic nut	Clinch, Perry County, Ill.	do	1¾	1	11,350	10.00	2.80	2.88	11.328	11.013
							Pana, washed nut.	Springside mine, Pana, Ill.	No. 5	3	1¼	11,094	10.00	2.968	3.048	12.265	
						E	Quaker nut	Christopher, Franklin County, Ill.	No. 6	2	1¼	12,500	9.00	3.16	3.22	11.500	
						F	Pana washed	Pana, Ill	do	3	1½	12,136	8.90	3.04	3.098	11.396	
Cincinnati (custom-house).	3,000	Coking; run of mine.	8	22	1.5	A	New River, Admiralty smokeless.	Fayette County, W. Va.	Sewell			14,900	5.00	2.58	2.60	7.790	7.730
						B	"C. C. and B." Pocahontas smokeless.	Tazewell County, Va., Mercer and McDowell counties, W. Va.	Pocahontas No. 3.			14,550	6.00	2.59	2.63	8.069	
						C	Jenner	Somerset County, Pa.	C′			14,500	6.50	2.67	2.72	8.374	
						D	White Oak, New River smokeless.	Macdonald, W. Va.	Sewell			14,800	5.00	2.57	2.59	7.812	
						E	New River smokeless.	Fayette County, W. Va.	do			14,750	4.75	2.71	2.725	8.247	
						F	do	do	do			14,850	4.00	2.71	[a]2.71	8.147	
Denver (mint).	2,500	Coking; run of mine.	12	38	1.5	A	Broadhead	Las Animas County, Colo.				12,300	12.00	4.45	4.49	16.297	
							Green Canyon	do				13,000	12.00	4.40	4.44	15.247	
						B	Greenville	Trinidad district, Colo.				12,456	10.00	3.92	[a]3.92	14.049	14.049
						C	Broadhead	Las Animas County, Colo.				12,300	12.00	4.30	4.34	15.752	
						D	Oak Hill	Routt County, Colo.				12,300	10.00	4.25	4.25	15.425	
Detroit (court-house and post-office, 1,400 tons; custom-house, 200 tons).	1,600	do	8	22	1.5	A	Kanawha gas	Elk Ridge mines Nos. 1 and 2, Armstrong Creek, W. Va.	Kanawha No. 2.			14,360	5.00	2.90	2.905	9.0311	9.016
						B	New River smokeless.	Prudence mine, Prudence, W. Va.				14,800	4.75	3.37	[a]3.37	10.166	
							Kanawha gas	Berlin mine, Wake Forest, W. Va.	Kanawha No. 2.			14,000	6.00	2.95	2.975	9.4866	
						C	Meadow Brook	Cannelton No. 2 mine, Cannelton, W. Va.	do			14,000	7.00	2.86	2.905	9.2634	
						A	Thick vein Pocahontas.	Elkhorn, McDowell, Empire, Turkey Gap, Mill Creek, and Coaldale mines, McDowell County, W. Va.	No. 3			15,000	5.00	3.30	3.305	9.8363	
						D	No. 2 Kanawha gas.	Handley and Elk Ridge, W. Va.		¾-inch lump.		14,250	6.00	3.25	3.275	10.260	
							do	do		Run of mine.		14,250	6.00	3.10	3.125	9.7901	
							Pocahontas	McDowell County, W. Va.	Pocahontas No. 3.	do		14,800	6.00	3.70	3.725	11.236	

[a] Standard.

TABLE 2.—*Schedule of proposals for coal, United States Treasury Department, fiscal year 1909–10*—Continued.

City.	Tons of 2,240 pounds.	Kind of coal (bituminous, except as otherwise stated).	Specified limits (per cent in "dry coal").			Bidder.	Commercial designation of coal.	Mine and location.	Coal bed.	Screen (dimensions in inches).		Heating value of coal "as received" (B. t. u.).	Ash in "dry coal" (per cent).	Price per ton.		Cost, in cents, per 1,000,000 B. t. u.	
			Ash.	Volatile matter.	Sulphur.					Through.	Over.			Bid.	Plus ash difference.	Comparative.	Actual.
Kansas City, Mo. (court-house and post-office).	2,000	Cherokee screened lump, or equal.	12	40	.....	A	Cherokee lump	Cherokee and Crawford counties, Kans.	......	......	[a] 1¾	12,900	11.50	$3 85	$3.88	13.428	13.324
						B	Cherokee deep-shaft screened lump.	.....do	......	......	[a] 2	13,100	10.00	4.144	[b]4.144	14.122	......
						C	.....do	Weir City and Mineral, Cherokee County, Kans.	......	......	[a] 2½	12,900	11.00	3.90	3.92	13.566	......
						D	Cherokee	Fleming, Cherokee County, Kans.	......	......	[a] 2	12,856	11.27	4.088	44.113	14.284	......
Louisville (court-house and post-office).	1,850	Coking; run of mine.	15	42	2.5	A	Pike Pittsburg	Monongahela River district.	Pittsburg	1¼ slack and nut.		13,000	11.00	2.12	2.22	7.623	7.280
						B	Pittsburg nut and slack.	Pittsburg district	......	1½ bar	......	13,550	9.00	2.42	2.48	8.171	......
						C	St. Bernard	St. Charles, Hopkins County, Ky.	No. 9	[a] 2½	......	11,500	13.00	1.95	2.09	8.113	......
						D	Roda	Wise County, Va.	......	Unscreened.		[c]14,200	8.00	2.50	2.54	......	......
						E	First pool, Pittsburg.	Monongahela River district.	......	......	1¼	13,500	7.00	2.50	2.52	8.333	......
						F	Black Raven	Rim, Bell County, Ky.	......	......	[d] 2	13,750	7.00	2.75	[c]2.77	8.994	......
						G	Westbourne	Cotula, Campbell County, Tenn.	......	......	[a] 1½	12,250	12.00	2.24	2.36	8.601	......
						H	Straight Creek	Bell County, Ky.	......	Run of mine.		14,500	6.00	2.78	[b] 2.78	8.559	......
						I	Pittsburg	Western Pennsylvania	......	......	[a] 1¼	12,900	10.50	2.32	2.41	8.340	......
						J	Fox Ridge	Bell County, Ky.	......	[a] 2	([c])	13,050	10.00	2.35	2.43	8.313	......
						K	Pittsburg	Monongahela River district.	......	......	1¼ bar	12,900	11.00	2.55	2.65	9.171	......
						L	Straight Creek	Straight Creek, Bell County, Ky.	......	[a] 1½	......	13,600	9.00	2.40	2.46	8.075	......
Milwaukee (post-office, court-house, and custom-house).	1,400	Youghiogheny, or equal.	11	35	2.5	A	Youghiogheny screenings.	Youghiogheny district	......	[d] 1	......	14,170	5.21	3.05	[b] 3.05	9.609	9.609
						B	.....do	.....do	......	⅜ bar.	......	13,500	11.00	3.00	3.116	10.304	......
						C	.....do	Washington County, Pa.	......	......	......	13,072	8.28	3.05	3.111	10.021	......

						D	do	Webster, West Newton, Pa.			1½ bar	12,196	14.25	3.10	3.281	12.010	
						E	do	Westmoreland and Washington counties, Pa.		1 bar.		13,106	9.95	3.02	3.115	10.611	
						F	do	Bertha mine, Bruceton, Allegheny County		¾ bar.		13,277	8.04	3.18	3.237	10.888	
						G	do	Youghiogheny district.		[d] 1½		13,466	9.67	3.07	3.159	10.473	
Minneapolis (post-office).	600	Youghiogheny lump, or Zeigler, or equal.	12	35	2.5	A	Youghiogheny, thin vein lump.	Westmoreland County, Pa.			¾ bar.	14,200	6.00	5.00	5.00	15.719	
						B	New River smokeless.	New River dist		Run of mine.		14,600	6.00	5.14	[b] 5.14	15.717	15.717
						C	Marrowbone	Hellier, Ky.	Upper Elkhorn.		1 bar.	14,000	6.00	5.38	5.38	17.156	
						D	Zeigler Purity	Christopher, Ill.	No. 6.		[a] 3	11,500	10.00	4.60	4.68	18.168	
							Marrowbone	Hellier, Ky.	Upper Elkhorn.		1 bar.	14,000	6.00	5.24	5.24	16.709	
						E	Youghiogheny screened lump.	Allegheny County, Pa.			do.	13,500	7.00	5.04	5.06	16.733	
						F	Hiawatha	Sesser, Franklin County, Ill.	No. 7.	6-inch lump.		12,791	7.00	4.70	4.72	16.474	
New Orleans: Custom-house.	1,450	Pratt lump No. 5, or equal.	10	35	3	A	Pratt lump	Pratt City, Ala.	Pratt	[a] 1½		14,500	6.00	3.25	[b] 3.25	10.006	10.006
						B	Pratt screened	Mineral Springs, Jefferson County, Ala.	do	2 bar.		14,000	8.00	3.19	3.23	10.300	
Mint	800	Pittsburg lump, or equal.	10	35	3	A	Pratt lump	Pratt City, Ala.	do	[a] 1½		14,500	6.00	3.25	[b] 3.25	10.006	10.006
						B	Pratt screened	Mineral Springs, Jefferson County, Ala.	do	2 bar.		14,000	8.00	3.25	3.29	10.491	
New York: Appraiser's warehouses.	2,500	Coking; run of mine.	8	22	1.5	A	Delta	Cambria County, Pa.				14,000	6.00	3.35	[b] 3.35	10.682	10.682
						B	Knickerbocker	Hooversville, Somerset County, Pa.		Run of mine.		14,000	8.00	3.60	3.64	11.607	
						C	Ætna	Portage, Pa.		do		14,200	8.00	3.43	3.47	10.909	
						D	Acme	Hawk Run, Clearfield County, Pa.		do		14,100	6.90	3.43	3.448	10.917	
						E	Somerset	Pine Hill and Elk Lick mines, Somerset County, Pa.		do		14,000	8.00	3.38	3.42	10.906	
						F	Pen-Mar	Macdonaldton, Somerset County, Pa.	B	do		14,000	8.00	3.37	3.41	10.874	
						G	Quemahoning	Jerome, Somerset County, Pa.	C′	do		14,300	7.00	3.47	3.49	10.896	
	2,500	Anthracite screenings.	18	9	1	D	Scranton	Pennsylvania		do		11.000	18.00	2.82	2.88	11.688	
						A	Pittston	Wyoming district				12,000	15.00	2.80	[b] 2.80	10.017	
						B		Pennsylvania				12,000	17.00	2.60	2.64	9.8215	9.673
Barge office.	500	No. 1 pea anthracite.	16	9	1	B	Pittston	Luzerne County, Pa.				12,190	14.00	4.30	[b] 4.30	15.748	15.748
						A	do	Wyoming district				12,000	16.00	4.46	4.50	16.592	
Custom-house.	2,500	No. 2 buckwheat anthracite.	18	9	1	A	do	do				11,000	18.00	3.38	3.38	13.718	
						B	do	Luzerne County, Pa.				11,150	18.00	3.05	3.05	12.212	12.212

[a] Round opening. [b] Standard. [c] Guaranteed calorific value not considered in making award. [d] Square opening. [e] Nut and slack.

TABLE 2.—*Schedule of proposals for coal, United States Treasury Department, fiscal year 1909-10*—Continued.

City.	Tons of 2,240 pounds.	Kind of coal (bituminous, except as otherwise stated).	Specified limits (per cent in "dry coal").			Bidder.	Commercial designation of coal.	Mine and location.	Coal bed.	Screen (dimensions in inches).		Heating value of coal "as received" (B. t. u.).	Ash in "dry coal" (per cent).	Price per ton.		Cost, in cents, per 1,000,000 B. t. u.	
			Ash.	Volatile matter.	Sulphur.					Through.	Over.			Bid.	Plus ash difference.	Comparative.	Actual.
New York—Con. Court-house and post-office.	11,000	Coking; run of mine.	8	22	1.5	A	Delta	Cambria County, Pa.				14,000	6.00	$3.37	a$3.37	10.746	10.746
						B	Knickerbocker	Hooversville, Somerset County, Pa.		Run of mine.		14,000	8.00	3.40	3.44	10.969	......
						F	Pen-Mar	Macdonaldton, Somerset County, Pa.	B			14,000	8.00	3.37	3.41	10.893	......
						G	Quemahoning	Jerome, Somerset County, Pa.	C′			14,300	7.00	3.57	3.59	11.208	......
						E	Somerset	Elk Lick and Pine Hill mines, Somerset County, Pa.				14,000	8.00	3.43	3.47	11.065	......
						C	Ætna	Portage, Pa.				14,200	8.00	3.47	3.51	11.035	......
						D	Acme	Hawk Run, Pa				14,100	6.90	3.58	3.598	11.391	......
Subtreasury	150	No. 1 pea anthracite.	16	9	1	A	Pittston	Wyoming district				12,000	15.00	4.07	4.155	15.458	......
						H	Plymouth	Plymouth, Pa.				12,870	10.75	4.07	a4.07	14.117	14.117
Omaha (court-house and post-office).	1,700	Coking; run of mine; screened lump.	12	40	.....	A	Cherokee	Englevale, Kans.		Run of mine.		12.000	11.00	4.64	a4.64	17.262	17.262
						B	Fleming	Fleming, Kans.	Weir-Pittsburg.			12,200	13.00	4.84	4.88	17.857	......
						C	Cherokee lump	Fuller and Mulberry, Kans.	do.		2	11,400	12.00	5.58	5.60	21.930	......
Philadelphia: Appraiser's stores.	350	Pea anthracite	16	9	1	A	Lehigh					11,865	15.80	3.49	3.537	13.308	13.131
						B	Deringer	Deringer, Pa.				12,315	13.45	3.85	a3.85	13.957	......
						C	Philadelphia and Reading white ash.	Schuylkill County, Pa.				12,000	16.00	4.40	4.451	16.559	......
Custom-house.	120	Egg anthracite	12	10	1.5	D	Lehigh Valley	Wyoming district				12,000	14.00	4.25	4.261	15.852	......
						B	Deringer	Deringer, Pa.				13,488	6.31	5.95	a5.95	19.693	19.693
						A	Lehigh					13,214	7.78	5.94	5.969	20.166	......
						C	Philadelphia and Reading white ash.	Schuylkill County, Pa.				12,500	12.00	6.40	6.514	23.204	......
Court-house and post-office.	700	Coking; run of mine.	8	22	1.5	D	Colonial colliery	Mount Carmel, Pa.				12,000	14.00	6.45	6.604	24.569	......
						C	Whitney	Clearfield County, Pa.	B			14,200	6.00	3.20	a3.20	10.061	10.061
						E	Acme	Hawk Run, Clearfield County, Pa.				14,000	7.80	3.35	3.380	10.797	......

						D	Eureka	Clearfield, Pa.				14,000	8.00	3.70	3.74	11.926	
						F	Blaine No. 1	Garrett County, Md.				14,000	8.00	3.13	3.17	10,108	
	2,800	Barley anthracite.	13			G	Susquehanna	Nanticoke, Pa.		1/16	3/32	11.500	13.00	2.35	2.35	9.123	9.123
						C	Philadelphia and Reading white ash.	Schuylkill County, Pa.				11.500	13.00	2.38	2.38	9.239	
						D	Colonial colliery.	Mount Carmel, Pa.			1/32	11,500	13.00	2.45	2.45	9.511	
Mint	3,500	Coking; run of mine.	8	22	1.5	A	Star Miller vein.	Twin Rocks, Cambria County, Pa.	B			14,300	5.00	3.04	[a]3.04	9.491	9.491
						B	Whitney	Clearfield County, Pa.	B			14,200	6.00	3.00	3.02	9.495	
						C	Acme	Hawk Run, Clearfield County, Pa.				14,000	7.20	3.05	3.094	9.866	
						D	Tyson	Elk Garden, W. Va.	Tyson			14,100	7.50	3.20	3.25	10.290	
						E	Jerome smokeless.	Somerset County, Pa.	C′			14,250	7.50	3.10	3.15	9.868	
						F	Somerset	Moro, Somerset County, Pa.				13,748	7.28	3.10	3.1456	10.239	
						G	Blaine No. 1	Garrett County, Md.				14,000	8.00	3.03	3.09	9.856	
Rochester (court-house and post-office).	600	Grate anthracite.	12	10	1.5	A	Kingston	Kingston, Pa.				13,449	7.07	6.30	6.3098	20.945	20.912
						B	Scranton	Scranton and Wilkes-Barre, Pa.				13,648	6.58	6.45	[a]6.45	21.098	
						C	Wilkes-Barre, grate.	Lehigh district				12,500	10.00	6.35	6.4184	22.923	
St. Louis (custom-house).	4,500	Coking; screened lump.	12	43	3	A	Mount Olive	Mount Olive, Ill.	No. 6		3	11,800	11.00	2.30	2.35	8.8908	
							Gillespie lump	Gillespie, Ill.	do		2	11,800	9.00	2.35	2.36	8.9286	
							Collinsville, No. 1 washed nut.	Collinsville, Ill.		3	1¾	11,500	10.00	2.30	2.33	8.8390	
						B	Staunton	Staunton, Ill.			2	11,300	10.00	2.14	2.17	8.5730	
						C	Equality	Equality, Ill.	No. 9		[b]2	12,000	12.00	2.27	2.34	8.7054	
						D	Cantine	Cantine, Ill.	No. 6		2	11,000	12.00	2.15	2.22	8.9286	
						E	Maryville	Maryville, Madison County, Ill.		2½	1½	11,000	12.00	2.10	2.17	8.9275	
						F	Majestic	Clinch, Ill.	No. 7	3	1¾	11,500	12.00	2.43	2.50	9.705	
						G	Staunton lump	Staunton, Ill.		1½	2	12,585	10.00	2.20	2.23	7.9105	7.804
							"B. B." lump	Belleville, St. Clair County, Ill.		1½	2	11,085	12.00	2.00	2.07	8.3366	
							Superior lump	Marion, Ill.		3	6	13,000	8.50	2.60	[a]2.60	8.9286	
Syracuse (court-house and post-office).	500	Egg anthracite.	12	10	1.5	A	Connell's	Bernice, Pa.				13,700	6.62	5.80	[a]5.80	18.90	18.90
						B	"D., L. and W."	Wilkes-Barre and Scranton, Pa.				12,500	12.00	6.35	6.4576	23.063	
						C	Lehigh Valley	Wyoming district				12,500	10.00	6.50	6.5676	23.456	
Toledo (custom-house).	500	New River, Georges Creek, Pocahontas smokeless lump, or equal.	8	22	1.5	A	"C. C. and B." Pocahontas smokeless.	Tazewell County, Va., Mercer and McDowell counties, W. Va.	Pocahontas No. 3.		3 bar	14,615	6.00	3.82	3.8596	11.790	
						B	New River smokeless.	Turkey Knob, Fayette County, W. Va.	Sewell		1¼ bar	14,800	4.02	3.79	[a]3.79	11.432	
						C	Quemahoning smokeless.	Jerome, Somerset County, Pa.	C′		3 bar	14,200	4.55	3.69	3.7006	11.634	
							Pocahontas smokeless.	Mercer and McDowell counties, W. Va.	No. 3		3 bar	15.300	4.38	3.80	3.8072	11.109	11.088

[a] Standard.

[b] Shaker screen.

TABLE 2.—*Schedule of proposals for coal, United States Treasury Department, fiscal year 1909-10*—Continued.

City.	Tons of 2,240 pounds.	Kind of coal (bituminous, except as otherwise stated).	Specified limits (per cent in "dry coal").			Bidder.	Commercial designation of coal.	Mine and location.	Coal bed.	Screen (dimensions in inches).		Heating value of coal "as received" (B. t. u.).	Ash in "dry coal" (per cent).	Price per ton.		Cost, in cents, per 1,000,000 B. t. u.	
			Ash.	Volatile matter.	Sulphur.					Through.	Over.			Bid.	Plus ash difference.	Comparative.	Actual.
Washington: Bureau of Engraving and Printing.	8,500	Run of mine	7	22	1.5	A	Parker	Barrellville, Md.				14,400	6.00	$3.50	$3.52	10.913	
						B	Orenda	Boswell, Somerset County, Pa.	C'			14,300	6.00	3.32	3.34	10.427	
							Jerome	Jerome, Somerset County, Pa.	C'			14,300	6.00	3.32	3.34	10.427	
							Elk Lick	West Salisbury, Somerset County, Pa.	Pittsburg			14,000	7.00	3.18	3.22	10.268	
						C	Star	Cambria County, Pa.	B			14,250	5.00	3.04	[a]3.04	9.524	
						D	New River	Fayette County, W. Va	Sewell			14,750	5.00	3.04	3.04	9.201	9.201
						E	Imperial	Pennsylvania	Moshannon			14,300	7.00	3.15	3.19	9.959	
							New River	West Virginia	Sewell			14,700	5.00	3.20	3.20	9.718	
						F	Moshannon	Clearfield County, Pa.	D			14,200	6.50	3.29	3.32	10.438	
						G		Fayette and Raleigh counties, W. Va.	Sewell and Fire Creek.			14,780	5.00	3.20	3.20	9.666	
						H	New River	Southside and Star mines, Thurmond, W. Va.	Sewell			14,700	5.00	3.07	3.07	9.323	
						I	Admiralty	Fayette County, W. Va.				14,600	6.00	3.25	3.27	9.999	
Butler Building.	250	Furnace anthracite.	14			A	Philadelphia and Reading.							5.80			
						B	do							5.85			
						C	Susquehanna							5.73			
						D	Philadelphia and Reading.							5.87			
						E	Mammoth; Philadelphia and Reading.							6.40			
						F	Girard mammoth.							5.74			
						G	Morea							5.57			
						H	Mahanoy Thomas.							5.71			
						I								5.68			
						J	Susquehanna							5.70			

Cox Building.	50	Egg anthracite.	14			A	Philadelphia and Reading.							6.24			
						B	do							6.12			
						C	Mammoth; Philadelphia and Reading.							6.60			
						D	Girard mammoth.							6.05			
						E	Morea							6.12			
						F	Mahanoy Thomas.							6.13			
						G	Lee Lyth, or William Penn.							6 24			
Stables, Nineteenth and E streets.	10	Stove anthracite.	16			A	Philadelphia and Reading.							6 85			
						B	do							6.62			
						C	Mammoth							6.90			
						D	Girard mammoth.							6.50			
						E	Morea							6.23			
						F	Mahanoy Thomas.							6.86			
						G	Lee Lyth, or William Penn.							6.65			
Treasury building.	800	Run of mine	7	22	1.5	A	Parker	Barrellville, Md				14,400	6.00	3.85	3.87	11.998	
						B	Orenda	Boswell, Somerset County, Pa.	C′			14,300	6.00	3.26	3.28	10.240	
							Jerome	Jerome, Somerset County, Pa.	C′			14,300	6.00	3.26	3.28	10.240	
							Elk Lick	West Salisbury, Somerset County, Pa.	Pittsburg			14,000	7.00	3.12	3.16	10.077	
						C	Star	Cambria County, Pa.	B			14,250	5.00	3.14	[a]3.14	9.837	9.837
						D	New River	Fayette County, W. Va	Sewell			14,700	5 00	3.35	3.35	10.174	
						E	Imperial	Pennsylvania	Moshannon			14,300	7.00	3.25	3.29	10.271	
							New River	West Virginia	Sewell			14,700	5.00	3.30	3.30	10.022	
						F	Moshannon	Clearfield County, Pa.	D			14,200	6.50	3.64	3.67	11.538	
						G		Fayette and Raleigh counties, W. Va.	Sewell			14,780	5.00	3.30	3.30	9.968	
						H	New River	Southside and Star mines, Thurmond, W. Va.	Sewell and Fire Creek.			14,700	5.00	3.42	3.42	10.386	
	75	Stove anthracite.	16			A	Philadelphia and Reading.							6.80			
						B	do							6.62			
						C	Mammoth							6.90			
						D	Girard mammoth.							6.50			
						E	Mahanoy Thomas.							6.83			
						F	Lee Lyth, or William Penn.							6.65			

[a] Standard.

TABLE 2.—*Schedule of proposals for coal, United States Treasury Department, fiscal year 1909–10*—Continued.

City.	Tons of 2,240 pounds.	Kind of coal (bituminous, except as otherwise stated).	Specified limits (per cent in "dry coal").			Bidder.	Commercial designation of coal.	Mine and location.	Coal bed.	Screen (dimensions in inches).		Heating value of coal "as received" (B. t. u.).	Ash in "dry coal" (per cent).	Price per ton.		Cost, in cents, per 1,000,000 B. t. u.	
			Ash.	Volatile matter.	Sulphur.					Through.	Over.			Bid.	Plus ash difference.	Comparative.	Actual.
Washington—Continued. Treasury building (cont'd).	1,200	No. 1 buckwheat anthracite.	21			A	Philadelphia and Reading.							$3.45			
						B	Girard mammoth.							3.49			
						C	Mahanoy Thomas.							3.77			
	1,200	No. 2 buckwheat anthracite.	21			A	Philadelphia and Reading.							3.00			
						B	Girard mammoth.							2.99			
						C	Mahanoy Thomas.							3.46			
Winder Building.	400	Run of mine	7	22	1.5	A	Parker	Barrellville, Md.				14,400	6.00	3.90	$3.92	12.152	
						B	Orenda	Boswell, Somerset County, Pa.	C′			14,300	6.00	3.26	3.28	10.240	
							Jerome	Jerome, Somerset County, Pa.	C′			14,300	6.00	3.26	3.28	10.240	
							Elk Lick	West Salisbury, Pa	Pittsburg			14,000	7.00	3.12	3.16	10.076	
						C	Star	Cambria County, Pa.	B			14,250	5.00	3.14	[a]3.14	9.837	9.837
						D						14,700	5.00	3.40	3.40	10.325	
						E	Imperial	Pennsylvania	Moshannon			14,300	7.00	3.25	3.29	10.271	
							New River	West Virginia	Sewell			14,700	5.00	3.30	3.30	10.022	
						F	Moshannon	Clearfield County, Pa.	D			14,200	6.50	3.69	3.72	11.695	
						G		Fayette and Raleigh counties, W. Va.	Sewell and Fire Creek.			14,780	5.00	3.35	3.35	10.118	
						H	Georges Creek	Frostburg, Md.				14,250	6.50	3.49	3.52	11.027	
	10	Stove anthracite.	16			A	"P. and R."							6.70			
						B	do.							6.62			
						C	Mammoth							6.90			
						D	Girard mammoth.	Schuylkill County, Pa.						6.50			
						E	Mahanoy Thomas.							6.61			
						F	Lee Lyth, or William Penn.							6.65			

[a] Standard.

SPECIFICATIONS FOR THE FISCAL YEAR 1909-10.

GENERAL CHARACTER.

The current contracts for coal purchased according to its heat value, which have been arranged alphabetically by cities in the table on pages 41-45, will serve as a guide for bidding on coal contracts for the fiscal year 1911. These contracts are all accompanied by the specifications given on pages 34-40.

Two classes of coal, anthracite and bituminous, are recognized and differentiated in the specifications. By anthracite is meant the coal mined in Susquehanna, Lackawanna, Luzerne, Carbon, Schuylkill, Columbia, Sullivan, Northumberland, and Dauphin counties, Pa. By bituminous coal is meant varieties other than anthracite, including the several grades of semibituminous and semianthracite.

The specifications for anthracite provide definite standards of quality for each size. These standards so far have been based on the percentage of ash in dry coal. In this connection it is well to know that the term "dry coal" means coal free from moisture, as determined by drying a small sample at 105° C. It is obvious that the percentage of ash in dry coal must be somewhat higher than in the undried sample.

Some of the anthracite coal bought for the Treasury Department is purchased on the specifications used for bituminous coal, which provide for payment according to the percentage of ash in "dry coal" and the number of British thermal units in coal "as received." It is probable that nearly all of the anthracite coal purchased during the fiscal year 1910-11 and future years will be purchased according to the double standard.

The specifications for bituminous coal are intended to describe clearly the character of the coal desired by the Government and to obtain from the bidder a definite statement of the quality of coal offered, with a view to using such statement as a standard, or as a basis for payment in connection with the price stated.

As will be seen from the specifications for bituminous coal, the bidder is not required to submit a sample of his coal, but is expected to state the percentage of ash in the "dry coal" and the number of British thermal units in the coal as it is to be delivered. If the bidder does not know the value of his coal, he may arrange to submit a properly selected sample with his bid, this sample to be analyzed by the Government and the results to be used as a standard under the contract. It is preferred, however, that the bidder give his own values.

The limits fixed in the specifications in the interest of plant economy are wide enough to permit the use of the output of any mine or group of mines, provided proper care is exercised in mining and picking out slate, bone, and other impurities. With these points in mind, it is only necessary for the bidder to select coal that will meet the description given and permit deliveries within the limits set.

It is not expected that all deliveries will be absolutely uniform or agree exactly with the standards established by the contractor, but it is necessary that all deliveries shall be within the limits set by the Government.

The standards established by the contractor should, however, be such as to require the least possible correction in price on account of variation in ash and heat units.

The heating value, expressed in British thermal units, of coal containing approximately the same percentage of ash is essentially a direct measure of its actual value to the purchaser, and for this reason the specifications provide for payment in proportion to the number of heat units contained in the coal as received. As the coal is weighed when delivered and payments are made according to the price per ton, it is necessary to determine the heat value of the coal in the condition in which it is received, with whatever moisture it may then contain.

Under this plan neither the contractor nor the Government will gain or lose by change in the moisture content of the coal between the time it is weighed at the mine and the time it is weighed on delivery. The price per ton will be correspondingly lower if the coal is wet, and higher if it is dry.

A further correction in payment is made for variation of the ash in dry coal in order to take account of the cost of handling additional fuel and ash and its effect on the capacity of the boiler and furnace.

FORM OF SPECIFICATIONS AND PROPOSAL.

The following is the general form of advertisement, including specifications, schedule, proposal, and guaranty, used in inviting bids for furnishing coal for the Government in the District of Columbia. Suitable modifications of these forms are used in other cities.

SPECIFICATIONS FOR SUPPLYING COAL FOR THE EXECUTIVE DEPARTMENTS AND INDEPENDENT ESTABLISHMENTS OF THE GOVERNMENT.

Office of General Supply Committee,
Washington, D. C., ...

Sealed proposals, in triplicate, to furnish the quantities of coal specified in the schedule herewith, required for use of the [name of department, bureau, or institution] for the fiscal year ending June 30, 19.., will be received until 2 o'clock p. m. ...., 19.., at the office of the general supply committee, Washington, D. C., and then opened.

Each bidder shall have the right to be present either in person or by attorney when the bids are opened.

ADDRESS OF PROPOSALS.

Proposals in triplicate must be forwarded to the general supply committee, Washington, D. C., postage prepaid. Addressed envelope for mailing is inclosed herewith.

PROPOSALS—GUARANTY.

Proposals must be made in triplicate on the form furnished by the general supply committee, and must be signed by the individual, partnership, or corporation making the same; when made by a partnership, the name of each partner must be signed. If made by a corporation, proposals must be signed by the officer thereof authorized to bind it by contract, and be accompanied by a copy, under seal, of his authority to sign.

The proposals must be accompanied by a guaranty from a corporate surety, duly qualified under the act of Congress approved August 13, 1894, or a guaranty signed by at least two responsible guarantors, that the bidder shall, within ten days after being called upon to do so, execute contracts in accordance with the terms of the proposal, and give a bond for the faithful performance thereof, with good and sufficient sureties as hereinafter required. The responsibility and sufficiency of the signers of such guaranty must be certified to by a judge or a clerk of a court of record or a United States attorney at or nearest to the place of business of the bidder. The guaranty must be in the penal sum of 10 per cent of the total amount of the bid: *Provided*, That $10,000 will be accepted as sufficient guaranty for a total bid of $100,000 or more. If preferred, a certified check for like amount, payable to the Secretary of the Treasury, may be filed in lieu of guaranty, the amount of said check to be forfeited to the Government in the event of failure on the part of the bidder to enter into contract in accordance with the proposal.

AWARD.

Bids will be considered on each item and on each building separately; and in determining the award of the contract consideration will be given to the quality of the coal (expressed in terms of ash in "dry coal" and British thermal units in coal "as received") offered by the respective bidders, the ability of the contractors to furnish the coal, and the responsibility of the parties submitting bids, as well as to the price per ton.

If the bidder to whom the first award may be made should fail to enter into a contract as herein provided, then the award may be annulled, and contract let to the next most desirable bidder, and such bidder shall be required to fulfill every stipulation embraced herein, as if he were the original party to whom the contract was awarded.

None of the contracts can in any case be lawfully transferred or assigned.

Contracts will be awarded only to established dealers in coal.

No proposal will be considered from any person, firm, or corporation in default of the performance of any contract or agreement made with the United States, or that is conclusively shown to have failed to perform satisfactorily such contract or agreement.

CONTRACTOR'S BOND.

Each contractor will be required to give bond with two or more individual sureties or one corporate surety (the latter preferred) duly qualified under the act of Congress approved August 13, 1894, in which they shall covenant and agree that, in case the said contractor shall fail to do or perform any or all of the covenants, stipulations, and agreements of said contract on the part of the said contractor to be performed as therein set forth, the said contractor and his sureties shall forfeit and pay to the United States of America the sum specified in said bond, to wit, a sum equal to 25 per cent of the estimated amount of the contract, for which said forfeiture the said contractor and his sureties shall be jointly and severally liable as fixed, settled, and liquidated damages, and not as a penalty, to be sued for in the name of the United States. Such sureties (except corporate sureties) shall justify their responsibility by affidavit showing that they severally own and possess property of the clear value in the aggregate of double the amount of the above-mentioned forfeiture over and above all debts and liabilities and all property by law exempt from execution; to be sworn to before a judge or a clerk of a court of record or a United States attorney, who must certify of his own personal knowledge that the sureties are sufficient to pay the full penalty of the bond.

If the estimated amount involved in the contract does not exceed the sum of $200, then the bond may be waived.

RESERVATIONS.

The right is reserved to the head of each department or independent establishment to reject any and all bids, to waive technical defects, and to accept any part of any bid and reject the other part if in his judgment the interests of the Government shall require it; also the right to annul any contract, if in his opinion there shall be a failure at any time to perform faithfully any of its stipulations, or in case of a willful attempt to impose upon the Government coal inferior to that required by the contract; and any action taken by the head of any department or independent establishment in pursuance of this latter stipulation shall not affect or impair any right or claim of the United States to damages for the breach of any of the covenants of the contract by the contractor.

The quantity of coal is based upon the previous annual consumption, but the right is reserved to order a greater or less quantity, subject to the actual requirements of the service.

The right is reserved to award the contract at a price higher than that named in lower bid or bids, the award to be based on the quality of the coal offered.

The right to reject any or all bids and to waive defects is expressly reserved by the Government.

DELIVERY.

The coal shall be delivered in such quantities and at such times as the Government may direct, deliveries to be made to any point, or points, within the District of Columbia as designated in the order.

The contractor will be allowed to deliver coal during the usual hours of teaming, or between 8 a. m. and dark.

For prompt settlement of accounts it is imperative that contractors shall notify the coal-inspection section of the United States Geological Survey during office hours on the day before deliveries are to be made that such deliveries are contemplated.

The coal will be weighed by representatives of the Government without expense to the contractor, as required by the act of March 2, 1895.

All charges for transportation and cartage must be prepaid by the contractor.

The available storage capacity of the coal bunkers will be placed at the disposal of the contractor to facilitate delivery of coal under favorable conditions. Information is furnished in the schedule herewith in relation to the several places at which the coal should be delivered, and the bidder is invited to visit those places and inspect the conditions.

After verbal or written notice has been given to deliver coal under this contract, a further notice may be served in writing upon the contractor to make delivery of the coal so ordered within twenty-four hours after receipt of said second notice. Should the contractor, for any reason, fail to comply with the second request, the Government will be at liberty to buy coal in the open market, and to charge against the contractor any excess in price of coal so purchased over the contract price.

SAMPLING.

As payment is based on the quality of the coal delivered as shown by analyses of representative samples, it is imperative that samples representing every order for coal shall be taken, and it shall be the duty of the proper officials of the government buildings at which coal is delivered to see that such samples are taken. The coal-inspection section of the United States Geological Survey will have general supervision of such sampling, giving instructions in the methods of taking representative samples and lending all possible assistance.

If practicable, the coal will be sampled when it is being delivered at the building. For small deliveries it may be necessary to take samples from the yards or bins. The sample taken should not be less than 100 pounds, to be selected proportionately from the lumps and fine coal, in order that it may in every respect truly represent the quality of the coal delivered.

In order to minimize the loss in the original moisture content and to obtain a uniform sample the gross sample will be pulverized as rapidly as possible until none of the fragments exceed one-half inch in diameter. The fine coal will then be mixed thoroughly and divided into four equal parts. Opposite quarters will be thrown out, and the remaining portions thoroughly mixed and again quartered, opposite quarters being thrown out as before. This process will be continued as rapidly as possible until the final sample thus obtained can be contained in a 2-pound can or jar and sealed air-tight.

The sample will then be forwarded to the chemical laboratory.

If desired by the coal contractor, permission will be given to him, or his representative, to be present and witness the quartering and preparation of the final sample to be forwarded to the government laboratories.

Immediately on receipt of the sample, it will be analyzed and tested by the method adopted by the American Chemical Society, and by the use of a bomb calorimeter. A copy of the result will be mailed to the contractor on the completion of the analysis and test.

ANTHRACITE COAL.

CHARACTER OF COAL.

Bids are desired on coal, 2,240 pounds to the ton, of the kinds and sizes shown in Table 3. To receive consideration bids must be based on the percentages of ash shown for the various classes of coal.[a]

These coals may be delivered from the car without being screened, but must be reasonably free from dust and fine coal.

Coal with less ash than the standard will be paid for at a higher price, and vice versa, in accordance with the provisions for payment.

TABLE 3.—*List of coals, showing contract standard and maximum limit of ash.*

Kind and size.	Ash in dry coal (per cent). Contract standard.	Ash in dry coal (per cent). Maximum limit.
White-ash anthracite:		
Furnace	10	14
Egg	10	14
Stove	12	16
Chestnut	14	18
Pea	16	20
No. 1 buckwheat	18	21
No. 2 buckwheat	18	21
Red-ash anthracite.		
Stove	12	16

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[a] The economic value of a fuel is affected by the actual amount of combustible matter it contains, as determined by its heating value shown in British thermal units per pound of fuel, and also by other factors, among which is its ash content. The ash content not only lowers the heating value and decreases the capacity of the furnace, but also materially increases the cost of handling the coal, the labor of firing, the cost of the removal of ashes, etc.

CAUSES FOR REJECTION.

It is understood that the coal delivered during the year will be of the character specified by the contractor. Coal containing more than 1 per cent of sulphur, an excessive amount of dust and fine coal, or a percentage of ash in excess of the maximum limits indicated in Table 3 will be subject to rejection.

PRICE AND PAYMENT.

Payment will be made at the price named in the proposal for the coal specified, corrected as indicated in Table 4[a] for variations in ash above and below the standard, as shown by analysis.

TABLE 4.—*Price corrections, in cents per ton, for anthracite coal, due to variations in ash in "dry coal" above and below the established standard.*

Ash in "dry coal" (per cent).	Size of coal.				
	Furnace and egg.	Stove.	Chestnut.	Pea.	Buckwheat.
6.01 to 6.50	24				
6.51 to 7.00	21				
7.01 to 7.50	18				
7.51 to 8.00	15	27			
8.01 to 8.50	Contract price.	24			
8.51 to 9.00		21			
9.01 to 9.50		18			
9.51 to 10.00		15	27		
10.01 to 10.50		Contract price.	24		
10.51 to 11.00			21		
11.01 to 11.50			18		
11.51 to 12.00			15		
12.01 to 12.50	15		Contract price.		
12.51 to 13.00	18			15	
13.01 to 13.50	21			12.5	
13.51 to 14.00	24			10	
14.01 to 14.50	....	15		7.5	
14.51 to 15.00	....	18		5	12
15.01 to 15.50	....	21		Contract price.	10
15.51 to 16.00	....	24			8
16.01 to 16.50	....	27	15		6
16.51 to 17.00	....	....	18		4
17.01 to 17.50	....	....	21	5.0	Contract price.
17.51 to 18.00	....	....	24	7.5	
18.01 to 18.50	....	....	27	10.0	
18.51 to 19.00	....	....	....	12.5	
19.01 to 19.50	....	....	....	15.0	4
19.51 to 20.00	....	....	....	....	8
20.01 to 20.50	....	....	....	....	14
20.51 to 21.00	....	....	....	....	21
21.01 to 21.50	....	....	....	....	32
21.51 to 22.00	....	....	....	....	48

NOTE.—Figures above heavy line represent cents per ton to be added to contract price; figures below heavy line represent cents per ton to be deducted from contract price.

BITUMINOUS COAL.

CHARACTER OF COAL.

Bids are desired on coal, 2,240 pounds to the ton, described as follows:

To meet the special requirements the coal will be designated as a good steam, coking, run-of-mine, or forge bituminous coal, free from dirt and excessive dust, and adapted for successful use in the particular furnace equipment for which the coal is desired. The foregoing information will be furnished by the Government as may be determined by boiler and furnace equipment, operating conditions, and the local market. The Government expressly reserves the right to have a practical service test made by the

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[a] Payment for anthracite coal purchased on the double standard of ash in "dry coal" and British thermal units in coal "as received" is made on the same basis as for bituminous coal (p. 39).

United States Geological Survey, the results to determine the final award of contract. The interested bidder or his authorized representative may be present at such test.

Coals containing ash in excess of 10 per cent, volatile matter in excess of 22 per cent, or sulphur in excess of 2.5 per cent, as shown by analyses of samples representing dry coal, will not be considered.

CAUSES FOR REJECTION.

A contract entered into under the terms of these specifications shall not be binding if, as the result of a practical service test of reasonable duration, the coal fails to give satisfactory results, due to its noncoking character, to excessive clinkering, to a prohibited amount of smoke, or to any other cause or causes which make it an undesirable fuel.

It is understood that the coal delivered during the year will be of the character specified by the contractor. It should therefore be supplied, if possible, from the same mine or group of mines.

Coal containing percentages of volatile matter and sulphur higher than the limits indicated herein and coal containing a percentage of ash in excess of the maximum limits indicated in the following table will be subject to rejection.

Payment for coal which has been delivered and used for trial or which has been consumed or remains on the premises at the time its quality is determined will be made at a price computed under the terms of these specifications.

Occasional deliveries of coal containing ash up to the percentage indicated in the column headed "Maximum limit for ash" may be accepted. Frequent or continued failure to maintain the standard established by the contractor, however, will be considered sufficient cause for cancellation of the contract.

PRICE AND PAYMENT.

On certification from the coal-inspection section of the United States Geological Survey that samples have been procured from deliveries constituting a completed order, payment will be made at once of 90 per cent of the amount of the bill, 10 per cent being withheld to protect the Government against the delivery of coal of inferior quality and to offset any deduction that may be determined by the United States Geological Survey from the average quality of all the deliveries on the order. On receipt of the Survey's report on the quality of the coal final settlement will be made.

If the 10 per cent withheld should prove insufficient to satisfy the claim of the Government on account of the delivery of fuel of low grade, the balance shall be deducted from the next succeeding order or orders.

Payment will be made at the price named in the proposal for the coal specified therein, corrected for variations in heating value and ash, as shown by analysis, above and below the standard established by the contractor in his proposal.

The correction in price for variations in British thermal units is a pro rata one and is determined by the following formula:

$$\frac{\text{Delivered B. t. u.}}{\text{Standard B. t. u.}} \times \text{contract price} = \text{price to be paid.}$$

For example, if a coal delivered on a contract guaranteeing 14,000 B. t. u. in coal "as received" at a price of $3 per ton shows by calorific test 14,300 B. t. u. in coal "as received," the price to be paid is found, by substitution in the formula, to be

$$\frac{14{,}300}{14{,}000} \times \$3 = \$3.064.$$

The price will also be further corrected for the percentage of ash. For all coal which by analysis contains less ash than that established in this proposal a premium of 1 cent[a] per ton for each whole per cent less ash will be paid. An increase in the ash content of 2 per cent over the standard established by contractor will be tolerated without exacting a penalty for excess of ash. When such excess exceeds 2 per cent above the standard established, deductions will be made from the price paid per ton in accordance with Table 5.

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[a] In the specifications for the fiscal year 1910–11 this premium will be 2 cents.

TABLE 5.—*Price corrections, in cents per ton, for bituminous coal, due to variations in ash in "dry coal" above and below the established standard.*

Contract standard, per cent of ash in "dry coal."	Maximum limit for ash (per cent).	Schedule of variations in ash (per cent).							
		Below—	Higher limits.						
5	12	7	7- 8	8- 9	9-10	10-11	11-12	12-13	13-14
6	13	8	8- 9	9-10	10-11	11-12	12-13	13-14	14-15
7	14	9	9-10	10-11	11-12	12-13	13-14	14-15	15-16
8	14	10	10-11	11-12	12-13	13-14	14-15	15-16	16-17
9	15	11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
10	16	12	12-13	13-14	14-15	15-16	16-17	17-18	....
11	16	13	13-14	14-15	15-16	16-17	17-18	18-19	....
12	17	14	14-15	15-16	16-17	17-18	18-19	19-20	....
13	18	15	15-16	16-17	17-18	18-19	19-20	20-21	....
14	19	16	16-17	17-18	18-19	19-20	20-21	21-22	....
15	19	17	17-18	18-19	19-20	20-21	21-22	....	....
16	20	18	18-19	19-20	20-21	21-22	22-23	....	....
17	21	19	19-20	20-21	21-22	22-23	....	....	....
18	22	20	20-21	21-22	22-23	....	....	....	....
Deduction (cents per ton)		0	2	4	7	12	18	25	35

It is important that the standards furnished with bids do not establish a higher value than can be maintained under the terms of the contract. In this connection it should be noted that the small mine samples as usually taken indicate a higher economic value than that of the coal delivered in carload lots, owing to the greater care exercised in separating extraneous matter from the coal of the mine sample. It is therefore evident that it will be to the interest of the contractor to furnish a correct description of the coal offered and an accurate statement of its actual value, as a failure to maintain the standard fixed by him will result in deductions from the contract price and may cause a cancellation of the contract, while coal of higher grade than that stated will be paid for at an increased price per ton.

SCHEDULE OF COAL REQUIRED BY THE EXECUTIVE DEPARTMENTS AND INDEPENDENT ESTABLISHMENTS OF THE GOVERNMENT FOR THE FISCAL YEAR ENDING JUNE 30, 19—.

[Here follows in tabulated form a list showing the departments or offices and places of delivery, the capacities and facilities for stowage, and the estimated amounts and kinds of coal required. The bidders are requested to furnish with each bid the commercial name of the coal they propose to deliver; the name and location of the mine or mines; the name or other designation of the coal bed or beds, and the price of coal offered per ton; and for bituminous coal (and also for anthracite when purchased on the double standard) the percentage of ash in "dry coal" and the calorific value in British thermal units of the coal "as received." These values become a part of the contract and constitute the standard according to which payment is made.]

GOVERNMENT CONTRACTS FOR COAL, FISCAL YEAR 1909-10.

Table 6 is a list of contracts made during the fiscal year 1909-10 for coal required for government use, under specifications providing for payment according to quality.

TABLE 6.—*Government contracts for coal for the fiscal year 1909–10.*

Location.			Estimated tons of 2,240 pounds.	Kind of coal (bituminous, except as otherwise stated).	Abstract of contract.					
City.	Place of delivery.	Department.			Commercial designation of coal.	Mine and location.	Bed.	Ash in dry coal (per cent).	B. t. u. as received.	Price per ton.
Albany	Custom-house	Treasury	250	Anthracite screenings				17	12,000	$2.40
Do.	do	do	250	Run of mine		Portage, Clearfield, Pa.	E	8	14,000	3.44
Baltimore	Appraiser's stores	do	100	do		Sugarloaf Nos. 2 and 3, Twin Rocks, Cambria Co., Pa.	B	5.5	14,400	3.13
Do.	Court-house and post-office.	do	2,250	do		do	B	5.5	14,400	3.13
Do.	Custom-house	do	500	Anthracite screenings				16	11,500	2.28
Do.	do	do	300	Run of mine		Sugarloaf, Cambria Co., Pa.	B	5.5	14,400	3.13
Boston	Post-office and subtreasury.	do	3,000	Anthracite screenings	Lehigh	Wilkes-Barre, Pa.		18	12,650	2.80
Do.	do	do	1,500	Run of mine	Pocahontas or New River.	West Virginia		6	14,350	3.82
Brooklyn	Court-house and post-office.	do	5,000	Buckwheat anthracite No. 2.		Pittston mine, Luzerne Co., Pa.		18	11,150	3.15
Buffalo	Post-office	do	1,000	Lump		Shawmut mines, Elk and Jefferson counties, Pa.	D	5	14,100	2.84
Chicago	Appraiser's stores	do	500	Washed nut	Pana	Pana, Ill	No. 6	8.9	12,136	3.04
Do.	Court-house and post-office.	do	8,000	do	do	do	do	8.9	12,136	3.04
Cincinnati	Custom-house	do	3,000	Run of mine	New River Admiralty.	Loup Creek, Fayette Co., W. Va.	Sewell	5	14,900	2.58
Denver	Court-house, post-office, and mint.	do	2,500	do	Green Canyon	Las Animas Co., Colo.		12	13,000	4.40
Detroit	Court-house and post-office.	do	1,400	do	Kanawha	Elk Ridge Nos. 1 and 2 mines, Armstrong Creek, W. Va.		5	14,360	2.90
Do.	Custom-house	do	200	do	do	do		5	14,360	2.90
Kansas City	Court-house and post-office.	do	2,000	Lump	Cherokee lump	Cherokee and Crawford counties, Kans.		11.5	12,900	3.85
Louisville	do	do	1,850	Slack and nut	Pike Pittsburg	Monongahela River, 50 miles above Pittsburg.	Pittsburg	11	13,000	2.12
Milwaukee	do	do	1,400	Screened	Youghiogheny			5.21	14,170	3.05
Minneapolis	Post-office	do	600	Lump	do	Westmoreland Co., Pa.		6	14,200	5.00
New Orleans	Custom-house	do	1,450	do	Pratt	Pratt mines, Pratt City, Ala.		6	14,500	3.25
Do.	Mint	do	800	do	do	do		6	14,500	3.25
Newport	Naval training station.	Navy	10,000	Run of mine	Atlantic Quemahoning.	Atlantic mine, Boswell, Pa.	C′	7	14,500	3.55
New York	Appraiser's stores	Treasury	2,500	Anthracite screenings	do	Pennsylvania		17	12,000	2.60
Do.	do	do	2,500	Lump	do	Delta mine, Cambria Co., Pa.		6	14,000	3.35

TABLE 6.—*Government contracts for coal for the fiscal year 1909–10*—Continued.

Location.			Estimated tons of 2,240 pounds.	Kind of coal (bituminous, except as otherwise stated).	Abstract of contract.					
City.	Place of delivery.	Department.			Commercial designation of coal.	Mine and location.	Bed.	Ash in dry coal (per cent).	B. t. u. as received.	Price per ton.
New York	Barge office	Treasury	500	Pea anthracite	Pittston	Pittston, Luzerne Co., Pa.		14	12,190	$4.30
Do.	Court-house and post-office.	do.	11,000	Run of mine		Delta mine, Cambria Co., Pa.		6	14,000	3.37
Do.	Custom-house	do.	2,500	Buckwheat anthracite No. 2.	Pittston	Pittston mine, Luzerne Co., Pa.		18	11,150	3.05
Do.	Navy-yard	Navy	40,000	Run of mine				9	14,250	2.67 2.72
Do.	Panama Railroad Co.		120,000	do.	Arico	Somerset Co., Pa.			14,400	2.64
Norfolk	Naval hospital	Navy	2,000	do.		Orange mine, Welch, W. Va.		6	14,600	2.85
Do.	Navy-yard	do.	15,000	do.		Big Vein Nos. 1 and 2, Pocahontas, Va.	Pocahontas No. 3.	4	14,800	2.57
Do.	Panama Railroad Co.		200,000	do.	Pocahontas				14,600	2.34
Do.	do.		200,000	do.	do.				14,600	2.44
Omaha	Court-house and post-office.	Treasury	1,700	do.	Cherokee	Englevale, Cherokee, and Crawford counties, Kans.		11	12,000	4.64
Pensacola	Navy-yard	Navy	2,700	Lump	Blocton Cahaba.			5.64	14,500	3.21
Philadelphia	Court-house and post-office.	Treasury	2,800	Barley anthracite	Susquehanna	Nanticoke, Pa.		13	11,500	2.35
Do.	do.	do.	700	Run of mine		Whitney No. 1, Clearfield Co., Pa.	B	6	14,200	3.20
Do.	Frankford Arsenal.	War	3,000	do.	Imperial	Viola mine, Osceola Mills, Pa.	B	6	14,250	2.75
Do.	Mint building	Treasury	3,500	do.	Star	Commercial collieries, Nos. 3, 4, and 5, Twin Rocks, Cambria Co., Pa.	B	5	14,300	3.05
Do.	Engineers' office	War	6,000	do.		Cambria Co., Pa.		8.5	14,100	2.90
Do.	do.	do.	10,000	do.		do.		8.5	14,100	3.30
Rochester	Court-house and post-office.	Treasury	600	Grate anthracite		Kingston, Pa.		7.07	13,449	6.30
Rock Island	Rock Island Arsenal.	War	1,000	Egg anthracite	Lehigh	Pennsylvania		10		8.59
Do.	do.	do.	5,000	Run of mine		Peerless mine, Springfield, Ill.	No. 5	12	10,900	2.12
Do.	do.	do.	300	do.		Knickerbocker Nos. 1 and 2, Hooversville, Pa.		5	13,600	4.75
St. Louis	Custom-house	Treasury	4,500	Lump		Staunton No. 2, Staunton, Ill.		10	12,585	2.20

Springfield	Springfield Armory.	War	5,000	Run of mine	Blossburg smokeless.	Morris Run and Spangler mines, Cambria Co., Pa.		7	14,400	4.14
Syracuse	Court-house and post-office.	Treasury	300	Egg anthracite		Bernice, Pa.		6.62	13,700	5.80
Toledo	Custom-house	do	500	Screened	Pocahontas	Greenbrier and Louisville mines.	Pocahontas No. 3.	4.38	15,380	3.80
Washington	Bethesda, Md.	Agriculture	50	Furnace anthracite				10		6.80
Do	do	do	25	Stove anthracite				12		6.35
Do	Main building	do	1,000	Furnace anthracite				10		5.45
Do	do	do	100	Egg anthracite				10		5.97
Do	do	do	75	Stove anthracite				12		6.25
Do	do	do	6,000	Run of mine	New River	Fayette Co., W. Va.	Sewell	5	14,750	3.10
Do	do	do	5	Forge				5	14,600	3.00
Do	Weather Bureau	do	800	Furnace anthracite				10		5.65
Do	do	do	8	Stove anthracite				12		6.55
Do	do	do	2	Forge	New River	Fayette Co., W. Va.	Sewell	5	14,600	3.10
Do	Bureau of the Census.	Commerce and Labor.	350	Egg anthracite				10		5.93
Do	Bureau of Fisheries.	do	150	do				10		5.97
Do	Bureau of Standards.	do	a 1,500	Furnace anthracite				10		6.55
Do	do	do	a 1,500	Buckwheat anthracite No. 1.				18		4.40
Do	Coast and Geodetic Survey.	do	225	Furnace anthracite				10		5.40
Do	Willard Building	do	165	do				10		5.59
Do	Botanical Gardens	Congress	350	do				10		5.47
Do	do	do	20	Chestnut anthracite				14		6.10
Do	Government Printing Office.	do	9,000	Egg anthracite				10		5.79
Do	Library of Congress.	do	3,700	Furnace anthracite				10		5.43
Do	Bureau of Education.	Interior	80	do				10		5.63
Do	Civil Service Commission.	do	250	do				10		5.61
Do	Freedmen's Hospital.	do	25	Egg anthracite				10		6.15
Do	do	do	1,925	Run of mine	Elk Lick	West Salisbury, Pa.	Pittsburg	7	14,000	3.11
Do	Geological Survey	do	600	Furnace anthracite				10		5.73
Do	Hospital for Insane.	do	1,000	Stove anthracite				12		5.62
Do	do	do	20,000	Run of mine	Georges Creek			6	14,250	3.00
Do	Howard University.	do	200	Furnace anthracite				10		5.80
Do	do	do	125	Stove anthracite				12		6.75
Do	Land Office	do	4,000	Run of mine	Georges Creek	Ocean mine, Allegany Co., Md.	Pittsburg	7	14,250	3.50
Do	Pension Office	do	975	Furnace anthracite				10		5.58
Do	6 Jackson place	Justice	30	Egg anthracite				10		6.15

a Alternate bid; all of either, part of both, but not all of both, will be delivered.

TABLE 6.—*Government contracts for coal for the fiscal year 1909–10*—Continued.

Location.			Estimated tons of 2,240 pounds.	Kind of coal (bituminous, except as otherwise stated).	Abstract of contract.					
City.	Place of delivery.	Department.			Commercial designation of coal.	Mine and location.	Bed.	Ash in dry coal (per cent).	B. t. u. as received.	Price per ton.
Washington	8 Jackson place	Justice	25	Egg anthracite				10		$6.10
Do	1435 K street	do	135	do				10		5.90
Do	1439 K street	do	30	do				10		6.22
Do	1000 Vermont avenue.	do	48	do				10		6.22
Do	United States Jail	do	25	Stove anthracite				12		6.22
Do	do	do	400	Run of mine	Star	Cambria Co., Pa	B	7	14,000	3.19
Do	Mills Building	Navy	[a] 450	Buckwheat anthracite No. 1.				18		3.45
Do	do	do	[a] 450	Buckwheat anthracite No. 2.				18		3.00
Do	do	do	[b] 200	Run of mine	Elk Lick	West Salisbury, Pa	Pittsburg	7	14,000	3.13
Do	Naval Medical School Hospital.	do	3,000	do	Georges Creek	Ocean mine No. 7, Frostburg, Md.		7	14,250	3.47
Do	Naval Observatory	do	600	Furnace anthracite				10		6.10
Do	do	do	15	Egg anthracite				10		6.44
Do	Navy-yard	do	15,000	Buckwheat anthracite No. 1.	Susquehanna			18		2.85
Do	do	do	15,000	do	Stanton or Thomas.			18		2.83
Do	Post-office annex	Post-office	400	Pea anthracite				16		4.10
Do	Post-office Building.	do	4,500	Run of mine	New River	Fayette Co., W. Va	Sewell	5	14,700	3.34
Do	Post-office carpenter shop.	do	6	Stove anthracite				12		6.50
Do	Zoological Park	Smithsonian Institution.	95	Furnace anthracite				10		6.40
Do	do	do	15	Stove anthracite				12		6.95
Do	do	do	15	Chestnut anthracite				14		6.95
Do	do	do	300	Run of mine	Imperial	Moshannon, Pa		5	14,700	3.90
Do	New National Museum.	do	3,000	do	New River	Loup Creek, Fayette Co., W. Va.	Sewell	5	14,750	3.25
Do	Old National Museum.	do	1,000	Furnace anthracite				10		5.44
Do	Smithsonian	do	4	Egg anthracite				10		6.05
Do	Bureau of Citizenship.	State	35	Furnace anthracite				10		5.75

Do	State stables	do	10	Stove anthracite				12		6.55
Do	State, War, and Navy Building.	State, War, and Navy.	[a]4,000	Buckwheat anthracite No. 1.				18		3.45
Do	do	do	[a]4,000	Buckwheat anthracite No. 2.				18		3.00
Do	do	do	[b]2,000	Run of mine	Elk Lick	West Salisbury, Pa	Pittsburg	7	14,000	3.12
Do	Bureau of Engraving and Printing.	Treasury	8,500	do	New River	Fayette Co., W. Va	Sewell	5	14,750	3.04
Do	Butler Building	do	250	Furnace anthracite				10		5.57
Do	Cox Building	do	50	Egg anthracite				10		6.05
Do	Treasury Building	do	75	Stove anthracite				12		6.50
Do	do	do	[a]1,200	Buckwheat anthracite No. 1.				18		3.45
Do	do	do	[a]1,200	Buckwheat anthracite No. 2.				18		2.99
Do	do	do	800	Run of mine	Star	Cambria Co., Pa	B	5	14,250	3.14
Do	Treasury stables	do	10	Stove anthracite				12		6.23
Do	Winder Building	do	10	do				12		6.50
Do	do	do	400	Run of mine	Star	Cambria Co., Pa	B	5	14,250	3.14
Do	Army Medical Museum.	War	325	Furnace anthracite				10		5.50
Do	1800 F street NW	do	44	Egg anthracite				10		6.09
Do	do	do	6	Stove anthracite				12		6.44
Do	Filtration plant	do	3,600	Run of mine				6	14,300	3.15
Do	Ford's old theater	do	350	Stove anthracite				12		6.35
Do	Isthmian Canal Commission.	do	125	Furnace anthracite				10		5.54
Do	Lemon Building	do	285	Egg anthracite				10		5.98
Do	610 Seventeenth street.	do	75	Furnace anthracite				10		5.50
Do	Soldiers' Home	do	300	Stove anthracite				12		6.45
Do	do	do	6,600	Run of mine	Orenda	Boswell, Pa		6	14,300	3.17
Do	War Department stables.	do	10	Egg anthracite				10		5.93
Do	do	do	10	Stove anthracite				12		6.44
Do	1712 G street NW	do	13	Egg anthracite				10		6.09
Do	do	do	8	Stove anthracite				12		6.44
Do	1725 F street NW	do	43	Egg anthracite				10		6.09
Do	1744 G street NW	do	70	do				10		6.09
Watertown	Watertown Arsenal.	do	400	Broken anthracite				10		5.75
Do	do	do	100	Stove anthracite	Lehigh	Lehigh, Luzerne Co., Pa		9		6.50
Do	do	do	5,000	Run of mine	New River	Sewell and Fire Creek mines		5	14,650	3.75
Wilmington [c]	Engineers' Office	do								

[a] Alternate bid; all of either, part of both, but not all of both, will be delivered.
[b] The superintendent reserves the right to purchase only such quantity as he deems necessary.
[c] Contract made anew each month.

ANALYSES AND RESULTS FOR THE FISCAL YEAR 1908-9.

AVERAGE QUALITY OF ANTHRACITE.

Not all of the anthracite coal purchased by the Government is paid for on the basis of ash values fixed by the Government; some of the contracts are made under specifications similar to those used for bituminous coal, which permit the bidder to establish the quality of the coal. In Washington, where the method of payment according to ash content as shown by analysis has been practiced, it is thought that the Government may at some time adopt exclusively the method that permits the bidder to establish the standards.

Table 7 shows the general average of moisture, heating value, volatile matter, and ash in the several sizes of anthracite coal delivered in Washington for the fiscal years 1907, 1908, and 1909.

TABLE 7.—*General average of quality of anthracite delivered to the Government in Washington, fiscal years 1907–1909.*

Size.	Moisture, 1906-7 [a] (per cent).	Volatile matter in dry coal, 1906-7 [a] (per cent).	B. t. u., 1906-7.[a]		Ash in dry coal (per cent).		
			As received.	Dry coal.	1906-7.	1907-8.	1908-9.
Furnace	4.08	2.42	12,861	13,408	10.44	10.00	10.73
Egg	4.16	3.10	12,961	13,523	10.57	10.83	11.55
Stove	....	....	....	....	....	12.05	13.20
Pea	4.81	3.02	11,886	12,487	16.04	16.23	15.62
No. 1 buckwheat	5.09	2.42	11,485	12,107	18.05	15.93	17.81
No. 2 buckwheat	....	....	....	....	....	17.13	....
Rice	....	....	....	....	....	....	19.30

[a] Not determined in succeeding years.

DETAILS OF ANALYSES.

Table 8 gives the analyses of coal delivered during the fiscal year 1908-9, showing the results of purchasing coal under specifications. The name of the city, the place of delivery, the description of the coal furnished, the estimated year's supply, the contract price per ton, and the standards of quality guaranteed are fully set forth at the head of each subdivision of the table. In the statement of the standards of quality percentage of ash is understood to refer to dry coal and B. t. u. to coal as received. The kind of coal referred to is bituminous except as otherwise stated, and the ton used is that of 2,240 pounds. The average corrected price per ton is based on the average analysis.

To give a general idea of the quality of the coal delivered during the year, the average quality of the coal delivered each month or of the coal covered by a certain part of the contract is stated. From these results, with their respective weights, the yearly average was determined. Some wide departures from the standard of monthly values will be noted, both as to penalty and as to bonus; but these departures so balance one another that the general average of results closely approximates that of the standards specified. This statement is true not only of monthly averages, but of averages covering longer periods.

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9.*

BALTIMORE, MD., COURT-HOUSE AND POST-OFFICE.

[Run of mine, B bed, Cambria County, Pa.; 2,250 tons at $3.19; 6.5 per cent ash, 14,300 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	89.865	1.75	13.31	78.81	6.13	2.80	6.24	14,675	14,936	$3.2737
August	139.297	1.70	20.28	69.79	8.23	2.04	8.37	14,189	14,435	3.1652
September	180.360	1.77	16.25	75.84	6.14	1.71	6.25	14,600	14,864	3.2569
October	145.842	1.49	21.48	70.95	6.08	1.90	6.18	14,579	14,800	3.2522
November	169.713	1.89	19.31	71.94	6.86	1.83	7.00	14,352	14,623	3.2016
December	255.497	1.42	18.03	73.98	6.57	1.50	6.66	14,517	14,727	3.2384
1909.										
January	115.491	2.78	18.90	72.38	5.94	1.85	6.11	14,480	14,894	3.2302
February	196.436	2.39	19.25	72.44	5.92	1.61	6.06	14,539	14,894	3.2433
March	279.681	1.87	19.41	71.07	7.65	2.96	7.80	14,216	14,487	3.1713
April	94.410	1.39	18.88	72.79	6.94	2.59	7.04	14,549	14,753	3.2455
June	98.379	2.86	19.48	71.21	6.45	2.21	6.64	14,133	14,549	3.1527
Total	1,764.971									
Average		1.89	18.73	72.69	6.69	2.06	6.82	14,430	14,708	[a]3.2190

BALTIMORE, MD., CUSTOM-HOUSE.

[Run of mine, B bed, Cambria County, Pa.; 300 tons at $3.19; 6.5 per cent ash, 14,300 B. t. u.]

1908.										
October	29.506	2.81	20.70	70.69	5.80	1.37	5.97	14,479	14,898	$3.2299
November	15.051	2.57	14.92	74.82	7.69	1.56	7.89	13,999	14,368	2.9892
December	21.406	1.63	18.01	74.64	5.72	1.51	5.81	14,700	14,944	3.2792
1909.										
January	41.046	1.60	18.98	73.34	6.08	1.72	6.18	14,610	14,848	3.2592
February	45.781	3.20	18.93	71.41	6.46	1.85	6.67	14,245	14,716	3.1777
April	37.529	1.47	19.57	72.37	6.50	1.62	6.69	14,475	14,691	3.2290
Total	190.319									
Average		2.22	18.91	72.56	6.31	1.64	6.51	14,444	14,770	[a]3.2221

BALTIMORE, MD., CUSTOM-HOUSE.

[Anthracite screenings, Mammoth vein, Mount Hope mine, Schuylkill region, Pa.; 500 tons at $2.74; 18 per cent ash.]

1908.										
October	20.663	4.46	7.24	73.61	14.69	0.71	15.38	12,040	12,602	$2.84
November	53.958	5.08	6.49	74.67	13.76	.93	14.50	12,155	12,806	2.86
December	45.575	7.09	6.51	73.24	13.16	.72	14.16	11,969	12,882	2.86
1909.										
January	78.932	7.15	6.95	71.68	14.22	.77	15.31	11,670	12,569	2.84
February	71.625	5.90	6.46	70.11	17.53	.72	18.63	11,290	11,998	2.74
March	57.755	2.77	6.13	70.33	20.77	.63	21.36	11,187	11,506	2.42
April	24.303	5.76	6.99	67.89	19.36	.69	20.54	10,642	11,292	2.53
Total	352.811									
Average		5.60	6.61	71.62	16.17	.75	17.13	11,581	12,268	[a]2.74

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[a] This corrected price per ton, wherever given in Table 8, is based on the average analysis.

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908-9*—Cont'd.

BOSTON, MASS., POST-OFFICE AND SUBTREASURY.

[Anthracite screenings; 3,000 tons at $2.80; 12 per cent ash, 12,650 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	165.298	3.15	2.98	85.97	7.90	.052	8.16	13,327	13,760	$2.9798
August	252.524	2.50	2.92	79.77	14.81	.73	15.19	12,388	12,706	2.7020
September	282.610	2.84	2.25	79.47	15.44	.47	15.89	12,109	12,463	2.6403
October	309.901	3.98	4.80	82.15	9.07	.49	9.45	12,840	13,372	2.8621
November	165.874	5.24	4.06	81.35	9.35	.59	9.87	12,689	13,391	2.8286
December	305.744	3.94	4.61	87.55	3.90	.56	4.06	13,848	14,416	3.1352
1909.										
January	319.587	2.24	4.59	82.52	10.65	.57	10.89	13,016	13,314	2.8910
February	239.244	2.67	5.44	79.76	12.13	1.21	12.46	12,610	12,956	2.7911
March	244.422	2.93	5.24	81.94	9.89	.66	10.19	12,862	13,250	2.8569
April	145.066	5.10	6.23	79.01	9.66	1.09	10.18	12,405	13,072	2.7558
May	252.007	3.79	5.99	80.77	9.45	.58	9.82	12,776	13,279	2.8479
June	164.312	4.28	6.25	78.98	10.49	.69	10.96	12,574	13,136	2.7932
Total	2,843.589									
Average		3.42	4.55	81.87	10.36	.66	10.62	12,827	13,281	2.8492

BOSTON, MASS., POST-OFFICE AND SUBTREASURY.

[Beech Creek run of mine, Pardee mine, Cambria County, Pa.; 1,500 tons at $4.43; 7.12 per cent ash, 14,257 B. t. u.]

1908.										
July	63.200	2.78	21.47	68.31	7.44	1.21	7.64	13,954	14,353	$4.3359
August	143.058	.90	21.95	70.76	6.39	1.47	6.45	14,534	14,666	4.5161
September	170.690	3.09	23.02	67.53	6.36	1.18	6.56	14,158	14,609	4.3992
October	141.762	2.46	16.47	72.41	8.66	1.06	8.88	13,841	14,190	4.3007
November	80.500	2.42	16.01	73.22	8.35	1.12	8.56	13,963	14,309	4.3396
December	186.035	3.30	16.65	71.72	8.33	1.01	8.62	13,844	14,316	4.3016
1909.										
January	157.187	.83	16.17	74.95	8.05	1.11	8.12	14,246	14,365	4.4266
February	122.594	.68	17.24	74.23	7.85	1.23	7.90	14,281	14,379	4.4375
March	70.218	.96	17.03	73.87	8.14	.97	8.22	14,157	14,294	4.3969
April	168.597	1.91	25.78	67.07	5.24	.90	5.34	14,377	14,657	4.4773
May	170.800	4.81	24.25	64.99	5.95	.90	6.25	13,790	14,487	4.2839
June	110.696	3.72	24.39	65.59	6.30	.96	6.54	13,816	14,350	4.2930
Total	1,585.337									
Average		2.42	20.31	70.13	7.14	1.10	7.32	14,087	14,436	4.3772

BROOKLYN, N. Y., COURT-HOUSE AND POST-OFFICE.

[No. 2 buckwheat anthracite, Pittston, Pa.; 3,500 tons at $3.38; 18 per cent ash, 11,150 B. t. u.]

1908.										
July	497.877	6.09	5.21	70.44	18.26	0.57	19.44	11,077	11,795	$3.3579
August	494.330	5.95	5.75	66.06	22.24	.64	23.65	10,548	11,215	3.0775
September	317.531	4.22	4.96	69.35	21.47	.79	22.42	11,145	11,636	3.3065
October	526.634	5.63	6.03	70.49	17.85	.56	18.92	11,218	11,888	3.4006
November	353.093	6.21	7.11	66.54	20.14	.73	21.47	10,940	11,664	3.2763
December	524.191	5.60	7.24	66.42	20.74	.67	21.97	10,967	11,617	3.2845
1909.										
January	607.982	6.02	8.50	66.20	19.28	.87	20.51	10,985	11,689	3.3100
February	169.935	7.64	6.52	67.60	18.24	.62	19.74	10,653	11,535	3.2293
March	744.696	5.64	7.43	69.30	17.63	.72	18.68	11,167	11,836	3.3652
April	86.379	7.82	9.76	64.63	17.79	.82	19.30	10,896	11,820	3.3030
May	560.971	5.77	8.61	66.50	19.12	.70	20.30	10,914	11,582	3.2885
June	238.123	3.89	14.90	63.00	18.21	.96	18.95	11,433	11,896	3.4658
Total	5,121.742									
Average		5.74	7.33	67.63	19.30	.71	20.47	11,010	11,680	3.3176

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908-9*—Cont'd.

BUFFALO, N. Y., POST-OFFICE.

[Punxsutawney, Florence, and Eleanora mines, Reynoldsville, Jefferson County, Pa.; 1,250 tons at $3; 6.5 per cent ash, 14,000 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
October	63.393	1.76	30.12	62.27	5.85	1.04	5.95	14,300	14,556	$3.0643
November	94.196	1.75	29.77	61.75	6.75	1.45	6.85	14,187	14,440	3.0401
December	132.589	3.02	29.62	60.03	7.33	1.16	7.56	13,920	14,354	2.9829
1909.										
January	163.750	2.74	29.90	60.87	6.49	1.26	6.68	14,183	14,583	3.0392
February	137.634	5.03	29.12	59.22	6.63	1.28	6.98	13,586	14,301	2.9113
March	132.500	3.96	29.34	60.83	5.87	1.17	6.11	13,891	14,463	2.9766
April	91.116	1.66	30.98	62.42	4.94	1.07	5.02	14,510	14,755	3.1193
May	78.705	2.82	30.04	61.43	5.71	1.36	5.88	14,057	14,465	3.0122
Total	893.883									
Average		3.04	29.79	60.85	6.32	1.23	6.52	14,040	14,480	3.0086

CHARLESTON, S. C., NAVY-YARD.

[Run of mine, Piney mine, Raleigh County, W. Va.; 3,000 tons at $4.03; 7 per cent ash, 14,500 B. t. u.]

1908.										
August	210	2.36	19.29	73.00	5.35	0.78	5.48	14,573	14,925	$4.0603
September	210	2.11	17.52	75.33	5.04	.60	5.15	14,629	14,945	4.0759
November	218	2.81	15.20	75.37	6.62	.76	6.81	14,301	14,715	3.9747
1909.										
January	200	2.98	20.66	71.95	4.41	.74	4.54	14,726	15,177	4.1128
February	252	2.84	25.17	67.65	4.34	.70	4.46	14,659	15,086	4.0942
	110	1.07	22.44	71.88	4.61	.87	4.66	14,915	15,076	4.1653
	150	2.24	25.30	67.83	4.63	.73	4.74	14,655	14,990	4.0931
April	275	2.71	24.06	67.53	5.70	.80	5.86	14,268	14,666	3.9755
	166	3.32	15.39	74.48	6.81	.73	7.04	14,178	14,665	3.9405
	270	1.96	20.20	73.19	4.65	.72	4.75	14,656	14,950	4.0934
Total	2,061									
Average		2.50	20.58	71.70	5.22	.74	5.35	14,533	14,905	4.0492

CHICAGO, ILL., APPRAISER'S STORES.

[Pawnee Nos. 1 and 2 nut, washed; Pawnee mines, Vermilion County, Ill.; 500 tons at $3.15; 10 per cent ash, 11,442 B. t. u.]

1908.										
July	33.080	6.35	32.31	49.06	12.28	2.42	13.11	11,757	12,553	$3.1967
August	29.364	6.98	30.02	53.07	9.93	1.59	10.68	12,127	13,037	3.3386
September	33.973	5.82	32.54	49.82	11.82	1.94	12.55	12,005	12,747	3.2850
October	30.223	7.21	33.31	50.11	9.37	1.42	10.10	12,167	13,113	3.3496
November	45.692	7.03	33.30	48.26	11.41	2.27	12.27	11,905	12,805	3.2575
December	43.850	8.62	30.88	46.65	13.85	2.28	15.16	11,321	12,389	2.9967
1909.										
January	44.379	7.09	33.17	46.91	12.83	2.94	13.81	11,548	12,429	3.1392
February	43.571	7.52	31.62	48.63	12.23	2.03	13.22	11,630	12,576	3.1618
March	43.225	5.99	34.41	47.08	12.52	3.41	13.32	11,830	12,584	3.2168
April	22.511	6.16	34.85	48.20	10.79	1.32	11.50	11,961	12,746	3.2929
May	38.527	6.27	34.80	46.57	12.36	2.99	13.19	11,757	12,543	3.1967
June	43.136	7.02	33.86	47.76	11.36	2.11	12.22	11,713	12,597	3.2046
Total	451.531									
Average		6.90	32.92	48.30	11.88	2.31	12.77	11,780	12,652	3.2431

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

CHICAGO, ILL., COURT-HOUSE AND POST-OFFICE.

[Pawnee Nos. 1 and 2 nut, washed; Vermilion County, Ill.; 8,000 tons at $3.15; 10 per cent ash, 11,442 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	207.183	8.89	32.03	50.41	8.67	1.77	9.52	11,908	13,071	$3.2783
	168.554	7.44	31.06	53.10	8.40	1.45	9.08	12,248	13,233	3.3719
August	173.192	7.59	30.74	53.60	8.07	1.84	8.73	12,345	13,359	3.4066
	214.842	7.51	31.16	53.69	7.64	1.54	8.26	12,420	13,429	3.4292
September	216.719	9.58	32.80	49.98	7.64	1.25	8.46	12,100	13,383	3.3411
	154.589	7.98	33.97	50.13	7.92	1.72	8.61	12,241	13,302	3.3800
October	182.377	8.12	32.95	51.52	7.41	1.02	8.07	12,332	13,422	3.4050
	195.375	9.02	33.98	50.00	7.00	1.20	7.69	12,281	13,499	3.4010
November	238.877	9.32	34.00	48.78	7.90	1.84	8.71	12,066	13,306	3.3315
	253.493	8.37	34.19	48.57	8.87	2.71	9.68	11,996	13,092	3.3025
	362.027	9.52	34.54	48.11	7.83	1.41	8.66	12,015	13,279	3.3177
December	350.147	9.20	33.61	50.19	7.00	1.34	7.71	12,255	13,497	3.3938
1909.										
January	376.846	8.56	34.51	49.52	7.41	1.84	8.10	12,184	13,325	3.3643
	319.292	7.61	34.36	50.61	7.42	1.91	8.03	12,385	13,405	3.4196
February	350.571	7.36	33.97	49.47	9.20	2.15	9.93	12,084	13,044	3.3267
	329.951	6.77	34.08	51.31	7.84	1.77	8.41	12,440	13,344	3.4348
March	314.373	7.04	34.53	50.28	8.15	1.70	8.78	12,258	13,186	3.3846
	310.105	6.78	35.82	49.61	7.79	1.91	7.79	12,385	13,286	3.4196
April	257.281	7.05	35.59	47.27	10.09	2.27	10.85	12,011	12,921	3.3066
	228.828	7.26	39.24	45.60	7.90	2.01	8.52	12,321	13,285	3.4020
May	216.025	6.86	35.33	49.84	7.97	2.11	8.56	12,321	13,228	3.4020
	132.545	6.20	36.96	48.78	8.06	2.19	8.59	12,353	13,170	3.4108
June	79.989	6.62	36.55	47.08	9.75	2.95	10.44	11,950	12,797	3.2899
	152.767	7.75	34.79	48.10	9.36	1.63	10.15	11,889	12,888	3.2731
Total	5,785.948	....	....	....	....	....	....	....	....	....
Average	....	7.93	34.23	49.78	8.06	1.79	8.76	12,215	13,267	3.3728

CINCINNATI, OHIO, CUSTOM-HOUSE.

[New River, Sewell bed, Fayette County, W. Va.; 3,000 tons at $2.93; 5 per cent ash, 14,800 B. t. u.]

1908.										
July	274.151	1.93	19.70	75.04	3.33	0.55	3.40	14,911	15,204	$2.9606
August	131.25	1.95	18.59	76.09	3.37	.62	3.44	15,034	15,334	2.9863
September	156.428	1.65	17.46	76.87	4.02	1.02	4.09	14,922	15,178	2.9542
October	277.1428	1.63	18.48	74.80	5.09	.66	5.18	14,753	14,999	2.9207
November	254.375	2.17	19.93	73.98	3.92	.74	4.01	14,795	15,122	2.9290
December	284.4196	2.40	19.66	73.91	4.03	.68	4.14	14,824	15,188	2.9348
1909.										
January	297.589	3.44	22.06	71.52	2.98	.64	3.09	14,835	15,363	2.9469
February	235.268	2.61	20.84	73.01	3.54	.71	3.64	14,789	15,285	2.9378
March	236.071	1.72	21.97	73.11	3.20	.74	3.26	14,876	15,136	2.9550
May	244.473	2.19	20.35	72.92	4.54	.64	4.64	14,622	14,950	2.8946
Total	2,391.168	....	....	....	....	....	....	....	....	....
Average	....	2.22	20.07	73.90	3.81	.69	3.91	14,823	15,160	2.9446

DETROIT, MICH., COURT-HOUSE AND POST-OFFICE.

[Kanawha run of mine, Berlin and Oakley mines, Sharon and Smithers, W. Va.; 1,400 tons at $3; 6.1 per cent ash, 14,000 B. t. u.]

1908.										
July	92.268	2.17	30.58	59.65	7.60	1.55	7.77	13,836	14,143	$2.9649
August	55.246	4.29	30.01	55.91	9.79	2.10	10.23	12,800	13,374	2.6729
September	73.942	1.62	30.26	61.02	7.10	1.80	7.22	14,180	14,413	3.0366
October	120.741	1.80	32.91	57.24	8.05	1.85	8.20	13,793	14,045	2.9356
November	93.402	2.63	32.06	58.58	6.73	1.56	6.92	13,932	14,308	2.9854
December	197.924	3.59	32.38	56.54	7.49	1.81	7.77	13,936	14,455	2.9863
1909.										
January	183.384	3.29	32.44	57.36	6.91	1.63	7.14	13,780	14,249	2.9529
February	160.576	2.83	32.69	57.74	6.74	1.55	6.94	13,968	14,375	2.9931
March	181.504	3.02	32.58	57.73	6.67	1.80	6.88	13,876	14,308	2.9734
April	85.504	1.59	33.98	58.79	5.64	1.28	5.73	14,295	14,526	3.0633
May	133.728	3.29	32.36	57.14	7.21	1.35	7.45	13,703	14,169	2.9364
Total	1,378.219	....	....	....	....	....	....	....	....	....
Average	....	2.84	32.24	57.76	7.16	1.66	7.37	13,858	14,263	2.9696

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

DETROIT, MICH., CUSTOM-HOUSE.

[Kanawha run of mine, Berlin and Oakley mines, Sharon and Smithers, W. Va.; 200 tons at $3; 6.1 per cent ash, 14,000 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
October	23.375	1.80	32.91	57.24	8.05	1.85	8.20	13,793	14,045	$2.9356
December	40.286	3.53	33.10	52.85	10.52	2.32	10.91	13,009	13,485	2.7176
1909.										
January	42.263	4.15	33.09	53.00	9.76	2.52	10.18	12,969	13,530	2.7091
February	20.563	2.18	31.79	58.95	7.08	1.76	7.24	13,915	14,225	2.9818
March	26.781	2.91	32.86	58.23	5.99	1.40	6.17	13,986	14,405	2.9970
April	8.344	3.01	31.86	56.78	8.35	1.21	8.61	13,488	13,907	2.8703
Total	161.612									
Average		3.14	32.82	55.37	8.67	2.36	8.96	13,422	13,857	2.856

KANSAS CITY, MO., COURT-HOUSE AND POST-OFFICE.

[Over 1¾" round-opening screen, Cherokee bed, Cherokee and Crawford counties, Kans.; 2,000 tons, at $4.368; 11.81 per cent ash, 12,894 B. t. u.]

1908.										
July	121.236	3.89	32.64	54.73	8.74	3.93	9.09	13,215	13,750	$4.4967
August	118.732	3.65	32.06	57.33	6.96	3.54	7.22	13,486	13,996	4.6085
September	136.969	2.93	38.22	48.57	10.28	4.26	10.58	13,247	13,648	4.4976
October	149.330	3.32	33.52	52.41	10.75	4.72	11.12	12,965	13,411	4.3921
November	141.388	3.24	32.23	49.51	15.02	7.11	15.52	12,132	12,538	4.0699
December	165.026	3.32	34.27	53.09	9.32	4.56	9.64	13,252	13,706	4.5093
1909.										
January	209.491	3.64	34.19	53.99	8.18	4.22	8.49	13,332	13,835	4.5464
February	189.765	3.99	33.48	53.26	9.27	4.24	9.65	13,126	13,671	4.4666
March	135.402	3.23	34.98	52.01	9.78	4.90	10.11	13,047	13,483	4.4198
April	155.678	2.82	33.27	51.81	12.10	4.77	12.46	12,755	13,125	4.3209
May	103.027	3.95	31.96	48.95	15.14	4.59	15.76	12,118	12,616	4.0651
June	145.357	4.02	33.12	52.50	10.36	4.39	10.79	12,852	13,346	4.3638
Total	1,771.401									
Average		3.50	33.73	52.43	10.34	4.60	10.71	12,989	13,460	4.4102

LOUISVILLE, KY., COURT-HOUSE AND POST-OFFICE.

[Through 1¼" bar screen, Camden mine, thin vein, Allegheny County, Pa.; 1,850 tons at $2.65; 6 per cent ash, 14,000 B. t. u.]

1908.										
July	116.565	2.28	28.17	58.23	11.32	1.63	11.58	12,990	13,290	$2.3388
August	108.950	3.05	27.82	55.72	13.41	1.94	13.83	12,602	12,999	2.1354
September	127.728	2.88	28.20	54.21	14.71	2.52	15.14	12,263	12,627	1.9712
October	120.128	2.89	31.16	53.92	12.03	1.33	12.38	12,867	13,250	2.2555
November	134.230	3.11	31.22	53.99	11.68	1.92	12.06	12,742	13,151	2.2319
December	157.805	4.09	32.98	53.90	9.03	1.28	9.41	13,111	13,670	2.4417
1909.										
January	138.321	4.63	32.13	53.64	9.60	.98	10.07	12,951	13,580	2.3814
February	128.134	4.67	30.57	53.57	11.19	1.22	11.74	12,831	13,458	2.3087
March	145.640	2.44	31.97	54.82	10.77	1.44	11.04	13,126	13,454	2.3646
April	113.955	3.08	30.87	53.97	12.08	1.23	12.46	12,771	13,177	2.2374
May	121.141	2.02	32.94	56.08	8.96	1.21	9.14	13,555	13,834	2.5258
June	103.549	1.78	32.32	56.30	9.60	1.58	9.78	13,348	13,589	2.4866
Total	1,516.144									
Average		3.13	30.95	54.79	11.13	1.51	11.49	12,930	13,348	2.3275

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

MILWAUKEE, WIS., COURT-HOUSE AND POST-OFFICE.

[Youghiogheny screenings, Pennsylvania; 1,200 tons at $3.50; 9.67 per cent ash, 13,466 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
August	380.000	3.78	29.15	57.82	9.25	1.46	9.60	13,095	13,610	$3.4036
November	148.016	4.62	30.85	54.16	10.37	.81	10.87	12,802	13,423	3.3274
December	159.000	7.87	28.87	52.79	10.47	1.24	11.37	12,379	13,437	3.2175
1909.										
January	229.000	5.81	29.42	53.81	10.96	1.56	11.64	12,487	13,257	3.2455
March	225.874	3.90	31.89	53.97	10.24	1.59	10.66	13,097	13,628	3.4041
	3.906	6.38	19.10	69.56	4.96	.78	5.30	13,778	14,717	3.6211
Total	1,145.796									
Average		4.89	29.89	55.13	10.09	1.39	10.61	12,839	13,499	3.337

MINNEAPOLIS, MINN., POST-OFFICE.

[Empire lump, Empire mine, No. 5 bed, Peoria County Ill.; 600 tons at $3.95; 14.78 per cent ash, 12,257 B. t. u.]

1908.										
August	61	13.89	32.95	39.56	13.60	2.55	15.79	10,500	12,194	$3.3838
November	98	13.79	32.43	39.10	14.68	2.56	17.02	10,249	11,888	3.2829
December	135	12.93	31.63	38.37	17.07	2.42	19.59	10,001	11,486	3.1530
1909.										
January	120	13.09	33.52	35.90	17.49	3.31	20.10	9,948	11,448	3.0859
February	75	11.90	31.23	36.55	20.32	4.21	23.06	9,594	10,890	2.7418
March	116	10.52	35.87	43.59	10.02	2.20	11.20	11,525	12,881	3.7441
April	36	9.07	32.92	51.20	6.81	.75	7.49	12,165	13,378	3.9904
Total	641									
Average		12.41	33.02	39.56	15.01	2.70	17.14	10,426	11,903	3.3399

MOBILE, ALA., LIGHT-HOUSE TENDER.

[Belle Ellen run of mine, Belle Ellen mine, Belle Ellen, Bibb County, Ala.; 3,000 tons at $3.25; 2.24 per cent ash, 14,780 B. t. u.]

1908.										
August		1.84	31.08	58.35	8.73	1.21	8.90	13,802	14,061	
November		1.81	34.07	58.78	5.34	.68	5.44	14,273	14,537	
1909.										
March		2.88	32.02	48.53	16.57	.71	17.06	11,880	12,232	
Average [a]		2.18	32.39	55.20	10.23	.87	10.46	13,318	13,615	

[a] Average irrespective of monthly amounts delivered.

NEW ORLEANS, LA., CUSTOM-HOUSE.

[Pratt lump, over 2" bar screen, Mineral Springs group, Jefferson County, Ala.; 1,300 tons at $3.25; 6 per cent ash, 14,000 B. t. u.]

1908.										
July	101.714	1.41	29.96	60.77	7.86	1.75	7.98	14,029	14,230	$3.2567
August	102.534	3.60	28.25	56.62	11.53	2.63	11.96	12,901	13,383	2.8749
September	113.071	1.12	28.03	61.23	9.62	2.00	9.71	13,899	14,056	3.1566
October	122.652	1.21	30.37	58.55	9.87	1.95	9.98	13,772	13,948	3.1571
November	104.397	1.24	30.19	59.15	9.42	2.21	9.54	13,832	14,006	3.1710
December	104.788	1.07	30.83	59.65	8.45	2.30	8.55	14,101	14,253	3.2534
1909.										
January	126.795	1.11	31.43	59.61	7.85	2.10	7.94	14,193	14,353	3.2948
February	113.228	1.25	30.88	58.80	9.07	1.68	9.19	13,957	14,127	3.2000
March	125.344	1.05	30.99	58.07	9.89	2.23	9.99	13,725	13,871	3.1462
April	101.372	1.04	31.91	58.00	9.05	2.10	9.15	13,952	14,098	3.1989
May	119.634	1.18	31.70	57.88	9.24	2.08	9.34	13,851	14,016	3.1754
June	101.335	.83	31.92	58.32	8.93	2.27	9.01	13,880	13,996	3.1821
Total	1,336.864									
Average		1.33	30.55	58.88	9.24	2.10	9.36	13,844	14,030	3.1738

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

NEW ORLEANS, LA., MINT BUILDING.

[Pratt lump, over 2" bar screen, Mineral Springs group, Jefferson County, Ala.; 800 tons at $3.40; 6 per cent ash, 14,000 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
August	96.621	3.00	29.79	59.17	8.04	1.60	8.29	13,466	13,882	$3.2503
September	74.087	1.46	26.08	57.01	15.45	1.90	15.68	12,834	13,024	2.7668
October	97.313	1.11	31.46	60.24	7.19	1.73	7.27	14,398	14,560	3.4967
November	67.817	1.44	31.66	59.68	7.22	1.95	7.33	14,178	14,384	3.4432
December	71.271	1.30	31.49	59.61	7.60	2.22	7.70	14,252	14,440	3.4612
1909.										
January	85.339	1.51	31.51	59.40	7.58	2.01	7.70	13,901	14,114	3.3760
February	76.321	1.55	31.41	58.77	8.27	1.93	8.40	13,990	14,210	3.3776
March	100.533	1.31	31.74	58.95	8.00	1.97	8.11	13,988	14,174	3.3771
April	75.837	1.34	32.41	58.26	7.99	1.92	8.11	14,058	14,249	3.3941
May	61.134	1.24	31.43	58.49	8.84	2.14	8.95	13,770	13,943	3.3241
June	2.118	1.28	21.68	68.02	9.02	1.96	9.14	13,922	14,103	3.3411
Total	808.391	....	....	....	....	....	....	....	....	....
Average	....	1.55	30.90	59.01	8.54	1.92	8.67	13,886	14,105	3.3509

NEWPORT NEWS, VA., PANAMA RAILROAD COMPANY.

[New River run of mine, 140,000 tons at $2.65 to $2.80;[a] 14,600 B. t. u.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	As received.	Dry coal.	Corrected price per ton.
1908.										
Apr. 22	[b] 680	2.46	....	....	....	....	5.40	14,602	14,970	$2.65
Apr. 29–May 2	[b] 4,544	2.46	....	....	....	....	5.00	14,611	14,979	2.65
June 5–8	[b] 4,562	3.21	....	....	....	....	5.04	14,439	14,918	2.64
June 13	[b] 698	3.18	....	....	....	....	4.81	14,461	14,936	2.64
June 19–22	[b] 5,585	2.66	....	....	....	....	4.96	14,536	14,934	2.65
July 2	[b] 1,068	3.04	....	....	....	....	5.18	14,488	14,943	2.64
July 3–6	[c] 4,591	2.41	....	....	....	....	5.29	14,482	14,840	2.64
July 9–11	[b] 5,090	2.97	....	....	....	....	4.35	14,440	14,882	2.64
July 17	[b] 1,147	2.11	....	....	....	....	4.39	14,429	14,740	2.64
July 21–22	[b] 4,993	2.68	....	....	....	....	5.06	14,545	14,946	2.65
Aug. 6 and 7	[b] 5,100	1.99	....	....	....	....	5.23	14,401	14,694	2.64
Aug. 11	[c] 715	2.30	....	....	....	....	4.51	14,629	14,973	2.65
Aug. 18–20	[c] 4,755	2.72	....	....	....	....	4.89	14,658	15,069	2.65
Sept. 10	[c] 764	3.15	....	....	....	....	3.99	14,687	15,165	2.80
Sept. 14 and 15	[b] 4,989	2.99	....	....	....	....	4.79	14,628	15,079	2.80
	[b] 4,739	2.31	....	....	....	....	5.16	14,660	15,006	2.80
Oct. 29–30	[c] 4,738	3.37	....	....	....	....	5.53	14,390	14,892	2.78
Nov. 2 and 3	[b] 4,933	2.96	....	....	....	....	4.46	14,613	15,058	2.80
Nov. 6–7	[b] 5,556	2.44	....	....	....	....	4.54	14,655	15,022	2.80
Nov. 23–24	[c] 4,573	2.92	....	....	....	....	5.28	14,578	15,016	2.80
Dec. 17–18	[b] 4,685	2.62	....	....	....	....	4.56	14,626	15,019	2.80
Dec. 31	[b] 4,322	3.17	....	....	....	....	4.98	14,516	14,991	2.80
1909.										
Jan. 5–6	[b] 4,938	2.68	....	....	....	....	4.70	14,693	15,098	2.80
Jan. 9–11	[c] 2,432	2.81	....	....	....	....	4.83	14,586	15,008	2.80
Feb. 4–5	[b] 4,791	2.13	....	....	....	....	4.63	14,706	15,206	2.80
Feb. 24–25	[b] 4,989	3.22	....	....	....	....	4.61	14,527	15,010	2.80
Feb. 28	[c] 5,517	3.54	....	....	....	....	4.60	14,563	15,097	2.80
Mar. 21–22	[b] 5,600	2.77	....	....	....	....	4.91	14,606	15,022	2.80
Mar. 31	[c] 4,777	2.73	....	....	....	....	4.13	14,703	15,115	2.80
Total	115,871	....	....	....	....	....	....	....	....	....
Average	....	2.77	....	....	....	....	4.84	14,570	14,985	....

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[a] Price f. o. b. steamers: April 1 to August 31, 1908, $2.65; September 1, 1908, to March 31, 1909, $2.80. Contract provides for a deduction of 1 cent per ton for each 100 B. t. u. below the standard.

[b] Delivered by contractor A.

[c] Delivered by contractor B.

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

NEW YORK, N. Y., APPRAISER'S WAREHOUSE.

[Run of mine, Pine Hill and Elk Lick mines, Somerset County, Pa.; 2,500 tons at $3.28; 8 per cent ash, 14,000 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	214.839	1.79	19.99	71.55	6.67	1.10	6.79	14,395	14,657	$3.3825
August	248.616	1.80	10.33	81.05	6.82	1.40	6.95	14,441	14,705	3.3933
September	133.317	2.11	17.98	72.94	6.97	1.20	7.12	14,398	14,708	3.3732
October	213.538	1.58	21.17	70.90	6.35	1.14	6.45	14,618	14,853	3.4348
November	252.695	2.53	20.89	70.10	6.48	1.22	6.65	14,260	14,630	3.3509
December	230.208	2.82	21.41	68.94	6.83	1.21	7.03	14,222	14,635	3.3320
1909.										
January	154.085	3.68	20.85	69.25	6.22	1.42	6.46	14,195	14,737	3.3357
February	344.801	2.27	21.09	69.83	6.81	1.42	6.97	14,223	14,553	3.3422
March	253.808	1.86	21.23	70.36	6.51	1.28	6.63	14,355	14,627	3.3732
April	258.221	2.99	21.59	68.62	6.80	1.39	7.01	14,045	14,478	3.2905
June	255.185	3.89	21.14	69.47	5.50	1.24	5.72	14,095	14,666	3.3223
Total	2,559.313									
Average		2.47	19.86	71.13	6.54	1.28	6.71	14,284	14,646	3.3565

NEW YORK, N. Y., APPRAISER'S WAREHOUSE.

[Anthracite screenings, Pennsylvania; 2,500 tons at $2.70; 18 per cent ash, 12,000 B. t. u.]

1908.										
July	150.201	4.22	4.79	77.15	13.84	0.82	14.45	12,266	12,806	$2.7899
August	125.962	5.18	4.65	74.97	15.20	.99	16.03	11,947	12,600	2.6981
September	335.446	4.78	4.58	76.88	13.76	.74	14.45	12,239	12,853	2.7838
October	62.458	5.82	6.46	73.92	13.80	.88	14.65	11,976	12,716	2.7246
November	263.607	4.84	6.70	71.82	16.64	.68	17.49	11,446	12,028	2.5754
December	152.614	5.62	6.42	74.34	13.62	.87	14.43	12,065	12,783	2.7446
1909.										
January	131.929	4.96	5.70	76.49	12.85	1.05	13.52	12,300	12,942	2.8075
February	104.663	3.91	5.41	79.21	11.47	1.04	11.94	12,709	13,226	2.9195
March	290.518	4.20	6.47	74.39	14.94	.85	15.59	12,056	12,585	2.7326
April	175.661	2.86	7.64	74.01	15.49	1.11	15.95	12,138	12,495	2.7511
May	112.047	5.48	7.71	75.76	11.25	.93	11.90	12,388	13,106	2.8473
June	179.317	5.00	7.57	74.94	12.49	.91	13.15	12,258	12,903	2.7981
Total	2,084.423									
Average		4.65	6.12	75.13	14.10	.87	14.79	12,105	12,695	2.7536

NEW YORK, N. Y., BARGE OFFICE.

[Pea anthracite, Mid Valley, Pennsylvania; 500 tons at $4.46; 14.89 per cent ash, 12,181 B. t. u.]

1908.										
November	64.933	3.88	5.12	77.73	13.27	0.91	13.81	12,491	12,995	$4.5835
December	112.779	4.63	6.04	72.91	16.42	.82	17.22	11,662	12,228	4.25
1909.										
February	106.605	2.89	9.75	72.53	14.83	1.00	15.28	12,553	12,926	4.5962
March	101.518	4.34	7.83	70.02	17.81	.94	18.61	11,435	11,954	4.1469
Total	385.835									
Average		3.95	7.38	72.85	15.82	.92	16.48	11,989	12,479	4.3897

TABLE 8.—*Analysis of coals delivered to the Government under contracts, 1908–9*—Cont'd.

NEW YORK, N. Y., COURT-HOUSE AND POST-OFFICE.

[Run of mine, Pine Hill and Elk Lick mines, Somerset County, Pa.; 11,000 tons at $3.43; 8 per cent ash, 14,000 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	404.893	2.74	18.00	73.01	6.25	1.05	6.42	14,269	14,672	$3.5059
	325.638	2.14	18.74	73.45	5.67	1.12	5.79	14,492	14,809	3.5705
	371.585	2.29	15.40	76.47	5.84	1.21	5.97	14,415	14,753	3.5517
August	525.857	1.36	20.79	72.12	5.73	1.19	5.81	14,647	14,849	3.6085
	540.362	1.36	19.21	73.58	5.85	1.28	5.94	14,672	14,873	3.6146
September	293.491	2.59	19.65	72.00	5.76	1.12	5.91	14,483	14,868	3.5683
	252.191	2.49	19.50	72.09	5.92	1.08	6.07	14,486	14,857	3.5591
October	655.705	2.45	22.13	69.66	5.76	1.19	5.91	14,431	14,793	3.5556
	470.348	2.27	21.33	70.62	5.78	1.16	5.91	14,472	14,807	3.5656
November	325.843	1.20	21.59	71.49	5.72	1.09	5.79	14,574	14,758	3.5906
	169.638	2.75	20.93	69.85	6.47	1.35	6.65	14,218	14,620	3.4934
December	798.174	3.30	21.79	69.02	5.89	1.16	6.08	14,208	14,695	3.4910
1909.										
January	327.866	1.01	21.71	71.71	5.57	1.41	5.62	14,697	14,847	3.6208
	267.321	3.08	21.45	69.54	5.93	1.20	6.12	14,322	14,778	3.5189
	664.152	2.99	21.55	69.56	5.90	1.25	6.08	14,319	14,760	3.5182
February	466	2.56	21.85	69.75	5.84	1.29	6.00	14,428	14,807	3.5549
	488.013	4.07	21.26	68.89	5.78	1.11	6.03	14,158	14,758	3.4787
March	797.772	2.71	21.04	70.38	5.87	1.15	6.04	14,333	14,732	3.5216
April	479.152	2.27	21.20	71.06	5.47	1.09	5.60	14,497	14,832	3.5718
	334.759	2.92	21.73	69.59	5.76	1.36	5.94	14,214	14,642	3.5024
May	220.960	1.44	22.23	70.98	5.35	1.01	5.43	14,538	14,751	3.5818
	665.098	2.30	22.11	69.75	5.84	1.16	5.97	14,316	14,652	3.5274
June	310.161	2.20	22.33	69.29	6.18	1.39	6.32	14,180	14,485	3.4841
Total	10,154.979									
Average		2.43	20.89	70.85	5.83	1.19	5.97	14,399	14,758	3.5478

NEW YORK, N. Y., CUSTOM-HOUSE.

[No. 2 buckwheat, Pittston anthracite, Pittston, Pa.; 4,000 tons at $3.10; 18 per cent ash, 11,150 B. t. u.]

1908.										
September	151.652	4.24	5.74	71.86	18.16	0.89	18.96	11,842	12,366	$3.2924
November	264.399	6.70	7.36	67.28	18.66	.66	20.00	11,000	11,889	3.0583
December	324.321	8.27	3.70	72.38	15.65	.67	17.05	11,190	12,200	3.1111
1909.										
January	486.779	6.82	6.48	67.08	19.62	1.05	21.05	10,743	11,529	2.9468
February	291.967	6.58	7.21	66.47	19.74	.73	21.13	10,816	11,577	2.9671
March	276.234	6.78	7.96	66.77	18.49	.67	19.84	10,872	11,663	3.0227
April	249.335	5.55	6.63	66.63	21.19	.96	22.43	10,843	11,480	2.9446
Total	2,044.687									
Average		6.65	6.42	68.13	18.80	.82	20.14	10,969	11,750	3.0294

NORFOLK, VA., NAVY-YARD.

[Run of mine, Oregon, Cephus, and Welch mines, W. Va.; 12,000 tons at $2.99; 5.5 per cent ash, 1 per cent sulphur, 14,500 B. t. u.]

1908.										
July	316.910	2.30	14.10	73.52	10.08	0.65	10.32	13,620	13,940	$2.7385
	515.800	1.45	14.14	74.43	9.98	.50	10.12	13,941	14,147	2.8047
	231.857	1.85	14.10	73.20	10.85	.43	11.06	13,667	13,925	2.7482
August	442.120	2.78	19.96	68.26	9.00	.89	9.26	13,644	14,034	2.7735
	449.62	2.65	16.20	73.18	7.97	.60	8.19	14,034	14,416	2.8739
	421.188	2.61	16.29	72.65	8.45	.68	8.68	14,063	14,440	2.8599
	344.263	2.75	18.29	70.22	8.74	.68	8.99	13,893	14,285	2.8248
September	417.834	2.38	13.82	75.12	8.68	.74	8.89	14,147	14,491	2.8772
	572.545	2.03	14.73	74.29	8.95	.76	9.14	14,064	14,355	2.8601
	418.303	2.10	16.68	73.46	7.76	.69	7.92	14,209	14,513	2.9100
October	371.406	2.38	17.12	72.51	7.99	.89	8.19	14,178	14,523	2.9036
	286.004	1.95	17.09	73.07	7.89	.71	8.05	14,176	14,458	2.9032
November	442.008	2.03	16.87	75.13	5.97	.90	6.09	14,447	14,746	2.9791
	433.683	1.59	17.46	75.20	5.75	.61	5.84	14,542	14,779	2.9987
	433.879	1.41	17.22	75.50	5.87	.57	5.96	14,635	14,840	3.0178
December	250.313	2.22	17.17	74.61	6.00	.80	6.14	14,538	14,867	2.9978
	206.949	1.45	15.41	76.26	6.88	.56	6.97	14,482	14,606	2.9863

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

NORFOLK, VA., NAVY-YARD—Continued.

[Run of mine, Oregon, Cephus, and Welch mines, W. Va.; 12,000 tons at $2.99; 5.5 per cent ash, 1 per cent sulphur, 14,500 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1909.										
January	444.420	2.05	16.82	74.96	6.17	1.00	6.30	14,601	14.906	$3.0108
	444.107	1.75	17.08	75.81	5.36	.63	5.45	14,760	15.023	3.0436
	444.196	2.16	17.17	75.58	5.09	.73	5.20	14,686	15,011	3.0284
	444.487	2.12	17.27	75.15	5.46	.75	5.58	14,628	14,944	3.0164
February	442.947	1.80	17.45	75.26	5.49	.66	5.59	14,673	14,943	3.0257
	442.969	1.48	17.38	75.86	5.28	.61	5.35	14,796	15,017	3.0510
	441.339	1.50	17.83	75.14	5.53	.63	5.62	14,754	14,978	3.0424
	442.7	2.06	17.40	75.22	5.32	.66	5.43	14,688	14,997	3.0288
March	441.763	1.66	17.34	76.34	4.66	.70	4.74	14,851	15,101	3.0624
	442.388	2.03	17.13	74.97	5.87	.73	5.99	14,530	14,831	2.9962
	220.268	2.19	17.37	75.02	5.42	.63	5.54	14,586	14,912	3.0077
April	403.795	3.01	17.38	72.09	7.52	.71	7.75	14,140	14,577	2.8958
	427.969	2.60	16.92	72.81	7.67	.69	7.87	14,146	14,524	2.8970
	438.326	2.91	17.76	73.85	5.48	.77	5.64	14,466	14,899	2.9630
May	433.884	1.58	13.94	77.04	7.44	.66	7.56	14,350	14,580	2.9391
	469.598	1.69	18.09	73.46	6.76	.57	6.87	14,338	14,583	2.9566
	509.754	2.02	18.34	72:87	6.77	.67	6.91	14,327	14,622	2.9543
June	454.911	2.66	17.41	74.12	5.81	.63	5.98	14,375	14,767	2.9642
	443.103	1.31	18.32	72.51	7.86	.62	7.97	14,237	14,426	2.9158
Total	15,087.606	....	....	....	....	....	....	....	....	....
Average	....	2.07	16.84	74.14	6.95	.68	7.10	14,350	14,653	2.9591

NORFOLK, VA., PANAMA RAILROAD COMPANY.

[Pocahontas run of mine; 260,000 tons at $2.65 and $2.80;[a] 14,600 B. t. u.]

1908.										
Apr. 24–25	5,090	1.65	....	....	....	....	6.05	14,668	14,914	$2.65
May 2–4	5,720	2.37	....	....	....	....	6.13	14,553	14,906	2.65
May 12	5,137	2.31	....	....	....	....	4.78	14,738	15,087	2.65
May 20–22	5,049.5	2.31	....	....	....	....	5.27	14,660	15,007	2.65
June 10–11	5,724	2.18	....	....	....	....	4.61	14,778	15,107	2.65
June 26–27	4,988	3.45	....	....	....	....	5.16	14,441	14,957	2.64
	5,048.5	2.73	....	....	....	....	4.81	14,640	15,051	2.65
July 16–17	5,731	2.08	....	....	....	....	5.10	14,687	14,999	2.65
July 22–23	4,842	2.22	....	....	....	....	5.49	14,594	14,925	2.65
July 25	5,473.5	2.87	....	....	....	....	5.71	14,499	14,927	2.64
Aug. 17–18	4,611	2.80	....	....	....	....	5.59	14,593	15,013	2.65
Aug. 21–24	5,590	3.50	....	....	....	....	6.19	14,400	14,922	2.63
Aug. 24–26	5,053	5.81	....	....	....	....	4.76	14,274	15,154	2.62
Sept. 5–7	5,468.5	2.70	....	....	....	....	5.94	14,581	14,985	2.80
Sept. 9–10	4,626	3.19	....	....	....	....	5.33	14,543	15,022	2.80
Oct. 1–2	5,040	2.42	....	....	....	....	6.27	14,517	14,877	2.80
Oct. 3–7	5,600	2.25	....	....	....	....	6.52	14,572	14,907	2.80
Oct. 22–24	5,009.5	1.79	....	....	....	....	5.89	14,607	14,873	2.80
Nov. 11–12	2,879	2.41	....	....	....	....	5.71	14,586	14,946	2.80
Nov. 27–28	5,098	1.93	....	....	....	....	5.65	14,615	14.903	2.80
Dec. 2–4	4,819	1.98	....	....	....	....	6.50	14,488	14,781	2.79
Dec. 7–9	5,613	2.53	....	....	....	....	6.21	14,403	14,777	2.79
Dec. 14–15	5,504.5	2.71	....	....	....	....	5.76	14,594	15.000	2.80
Dec. 28–29	4,763.5	1.77	....	....	....	....	7.84	14,335	14,593	2.78
1909.										
Jan. 11–12	5,515	2.19	....	....	....	....	7.10	14,397	14,719	2.78
Jan. 20–21	5,027	2.53	....	....	....	....	7.20	14,323	14,695	2.78
Jan. 25–26	5,521	2.38	....	....	....	....	6.66	14,454	14,806	2.79
Jan. 30	5,298.5	1.83	....	....	....	....	6.42	14,527	14,798	2.80
Feb. 9–10	3,289.5	2.62	....	....	....	....	5.54	14,618	15,011	2.80
Feb. 13–15	5,621	2.29	....	....	....	....	6.22	14,509	14,849	2.80
Feb. 18–19	4,710	2.13	....	....	....	....	5.87	14,645	14,964	2.80
Mar. 3–4	4,151	2.80	....	....	....	....	5.96	14,472	14,889	2.79
Mar. 5–6	5,005	2.31	....	....	....	....	6.06	14,544	14,888	2.80
Mar. 13	4,774	2.96	....	....	....	....	6.13	14,303	14,739	2.78
Mar. 17–18	4,666	2.52	....	....	....	....	6.68	14,363	14,734	2.78
Mar. 26–27	5,437	2.16	....	....	....	....	7.22	14,331	14,647	2.78
Total	181,493.5	....	....	....	....	....	....	....	....	....
Average	....	2.51	....	....	....	....	5.97	14,524	14,898	....

[a] Price f. o. b. steamers: April 1 to August 31, 1908, $2.65; September 1, 1908, to March 31, 1909, $2.80.

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

OMAHA, NEBR., COURT-HOUSE AND POST-OFFICE.

[Cherokee run of mine, Englevale, Kans.; 1,700 tons at $4.41; 11 per cent ash, 12,000 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	45.826	5.14	21.58	49.75	23.53	3.42	24.78	10,459	11,026	$3.4937
August	26.304	3:41	29.52	51.62	15.45	5.17	16.00	12,119	12,547	4.3837
September	43.116	3.82	27.40	46.35	22.43	7.58	23.32	10,757	11,184	3.6032
October	121.674	4.29	30.91	48.03	16.77	5.88	17.53	11,399	11,909	4.0091
November	217.759	4.02	30.25	48.07	17.66	4.88	18.42	11,732	12,223	4.0615
December	260.290	4.23	30.23	48.89	16.65	7.15	17.39	11,824	12,346	4.1653
1909.										
January	293.674	4.41	30.87	47.43	17.29	5.88	18.09	11,653	12,190	4.0325
February	175.031	4.14	30.73	48.60	16.53	5.71	17.24	11,816	12,325	4.1624
March	167.268	5.97	32.39	50.66	10.98	3.53	11.68	12,313	13,095	4.5250
April	154.216	5.96	32.01	46.33	15.70	4.58	16.69	11,491	12,216	4.1029
May	99.643	6.87	32.03	44.69	16.41	3.37	17.63	11,221	12,049	3.9437
Total	1,604.801									
Average		4.74	30.63	48.09	16.54	5.37	17.35	11,666	12,246	4.1073

PHILADELPHIA, PA., APPRAISER'S STORES.

[Deringer pea anthracite, Deringer mines, Pa.; 350 tons at $3.89; 14.95 per cent ash.]

1908.										
October	30	4.95	4.43	78.21	12.41	0.58	13.06	12,337	12,979	$4.0150
November	42	5.28	3.92	76.22	14.58	.40	15.39	11,897	12,560	3.89
December	69	4.91	5.73	73.91	15.45	.60	16.25	11,785	12,395	3.89
1909.										
January	63	5.23	5.35	72.69	16.73	.85	17.65	11,578	12,217	3.815
February	45	5.31	3.82	74.82	16.05	.62	16.95	11,611	12,262	3.89
March	45	5.42	5.02	75.02	14.54	.64	15.37	11,859	12,539	3.89
April	51	4.75	5.77	75.69	13.79	.52	14.47	12,023	12,623	3.965
Total	345									
Average		5.11	4.99	74.87	15.03	.62	15.84	11,831	12,468	3.89

PHILADELPHIA, PA., COURT-HOUSE AND POST-OFFICE.

[Mount Hope pink-ash barley anthracite, Mount Hope mine, St. Clair, Schuylkill County, Pa.; 2,860 tons at $2.35; 14 per cent ash, 11,000 B. t. u.]

1908.										
August	134.054	7.12	6.22	67.06	19.60	0.58	21.10	10,449	11,249	$1.9823
September	241.875	6.47	2.72	72.51	18.30	.55	19.57	11,197	11,972	2.2721
October	233.795	6.21	5.41	70.44	17.94	.63	19.12	11,214	11,956	2.2757
November	289.125	7.00	4.42	71.30	17.28	.70	18.58	10,994	11,822	2.2787
December	393.973	5.89	6.03	70.37	17.71	.88	18.82	11,234	11,937	2.3300
1909.										
January	362.866	6.21	5.17	71.81	16.81	.77	17.92	11,424	12,180	2.4006
February	307.339	7.24	3.91	69.95	18.90	.40	20.37	10,558	11,382	2.0756
March	371.435	6.13	5.10	71.88	16.89	.79	17.97	11,259	11,994	2.3653
April	271.607	7.33	6.64	70.42	15.61	.70	16.85	11,241	12,112	2.3815
May	208.857	6.30	6.71	69.69	17.30	.67	18.46	11,153	11,903	2.3127
June	213.406	6.80	6.20	71.45	15.55	.72	16.68	11,341	12,168	2.4029
Total	3,028.332									
Average		6.55	5.26	70.83	17.36	.69	18.58	11,132	11,912	2.3082

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

PHILADELPHIA, PA., COURT-HOUSE AND POST-OFFICE.

[Acme run of mine, Acme Slope mine, Hawk Run, Clearfield County, Pa.; 350 tons at $3.30 and $3.35;[a] 7.8 per cent ash, 14,000 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
August	48.491	3.82	18.42	70.70	7.06	2.13	7.34	14,021	14,578	$3.3550
September	50.688	2.19	17.64	72.61	7.56	2.07	7.72	14,277	14,597	3.4163
October	41,625	1.63	20.81	70.04	7.52	2.10	7.64	14,266	14,502	3.4137
November	65.478	1.84	20.86	70.00	7.30	2.02	7.44	14,314	14,582	3.4251
December	24.018	2.69	21.17	68.81	7.33	2.04	7.53	14,105	14,495	3.3751
1909.										
January	80,504	2.17	21.23	69.14	7.46	1.92	7.63	14,186	14,501	3.3945
February	48.701	2.30	21.23	68.47	8.00	2.13	8.19	14,074	14,366	3.3677
March	31.078	2.60	21.35	68.27	7.78	2.08	7.99	13,998	14,372	3.3495
April	32.920	2.22	21.40	67.81	8.57	2.59	8.76	13,931	14,247	3.2837
May	30.384	2.21	21.51	67.68	8.60	2.41	8.79	13,935	14,250	3.2847
June	29.152	2.33	21.22	68.94	7.51	2.11	7.69	14,086	14,422	3.3203
Total	483.039									
Average		2.33	20.52	69.52	7.63	2.11	7.81	14,140	14,477	

[a] Price per ton: April 1 to June 30, 1908, $3.30; July 1, 1908, to March 31, 1909, $3.35.

PHILADELPHIA, PA., FRANKFORD ARSENAL.

[Buckwheat anthracite, 1,000 tons at $2.65; 17 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	As received.	Dry coal.	Corrected price per ton.
1908.										
July	140						19.13			$2.51
August	420						19.66			2.44
September	455						17.91			2.65
October	35						23.21			
November	35						15.82			2.69
Total	[a] 1,085									
Average							18.85			2.57

[a] Deliveries amounted to 31 cars, estimated at 35 tons each.

PHILADELPHIA, PA., FRANKFORD ARSENAL.

[Run-of-mine, Clearfield County, Pa., 5,000 tons at $2.79; 5 per cent ash, 14,000 B. t. u.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	As received.	Dry coal.	Corrected price per ton.
1908.										
July	350	2.20					5.25	14,641	14,970	$2.9177
August	70	3.38					5.56	14,461	14,967	2.8819
September	280	2.31					5.61	14,674	15,021	2.9243
October	350	2.63					5.45	14,649	15,044	2.9193
November	455	2.66					5.60	14,550	14,947	2.8996
December	875	2.71					5.49	14,524	14,930	2.8944
1909.										
January	840	2.87					5.35	14,555	14,985	2.9006
February	490	3.32					5.25	14,506	15,004	2.8908
March	350	2.84					5.15	14,601	15,028	2.9098
April	420	2.73					5.40	14,511	14,918	2.8918
May	175	3.70					7.58	14,012	14,550	2.7724
Total	[a] 4,655									
Average		2.79					5.48	14,542	14,959	2.8980

[a] Deliveries amounted to 133 cars, estimated at 35 tons each.

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

PHILADELPHIA, PA., LEAGUE ISLAND NAVY-YARD.

[Run of mine, Lower Kittanning bed, Blaine mine No. 1, Dill, W. Va., 16,000 tons at $2.92; 7 per cent ash (8 per cent, including sulphur), 14,250 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July		1.29	13.54	77.38	7.79	1.62	7.89	14,210	14,396	$2.9118
		1.51	14.00	76.28	8.21	1.65	8.34	14,359	14,579	2.9423
August		2.27	12.50	75.02	10.21	1.51	10.45	13,718	14,037	2.7710
		5.48	15.06	71.87	7.59	1.40	8.03	13,750	14,547	2.8175
September		2.28	14.53	73.48	9.71	1.89	9.94	13,942	14,267	2.8369
		6.56	12.56	73.36	7.52	1.74	8.05	13,560	14,512	2.7786
October		2.79	15.49	73.36	8.36	1.49	8.60	14,054	14,457	2.8798
		2.34	15.26	73.29	9.11	1.46	9.33	14,002	14,338	2.8492
		2.13	15.58	74.25	8.04	1.74	8.22	14,174	14,482	2.9044
		3.34	15.70	72.98	7.98	1.65	8.26	13,886	14,366	2.8454
November		2.15	14.47	72.47	10.91	1.63	11.14	13,649	13,949	2.7268
		2.90	16.38	72.51	8.21	1.68	8.46	13,973	14,390	2.8632
		1.87	16.25	73.20	8.68	1.97	8.84	13,994	14,258	2.8675
December		2.80	16.00	71.75	9.45	2.00	9.72	13,676	14,070	2.7824
		4.75	13.93	71.63	9.69	1.74	10.18	13,399	14,067	2.7056
		3.89	14.85	71.53	9.73	1.61	10.12	13,474	14,019	2.7210
		3.40	15.22	72.72	8.66	1.87	8.96	13,755	14,239	2.8186
1909.										
January		2.93	15.58	72.15	9.34	1.83	9.62	13,771	14,187	2.8018
		3.56	15.24	72.47	8.73	1.69	9.05	13,835	14,346	2.8150
		4.12	15.86	71.50	8.52	1.97	8.89	13,640	14,226	2.7950
		2.40	15.70	70.68	11.22	2.20	11.49	13,488	13,820	2.6939
		3.16	15.52	72.72	8.60	1.75	8.88	13,760	14,209	2.8196
February		2.98	15.88	69.72	11.42	2.24	11.78	13,393	13,804	2.6744
		3.51	16.00	70.95	9.54	1.77	9.89	13,704	14,202	2.7881
		5.01	14.72	71.05	9.22	1.66	9.71	13,499	14,211	2.7461
March		3.96	16.22	70.20	9.62	1.80	10.02	13,467	14,022	2.7196
		2.84	15.32	72.81	9.03	1.43	9.29	13,773	14,176	2.8023
April		2.05	16.16	72.80	8.99	1.70	9.18	13,880	14,171	2.8242
		4.97	21.16	64.57	9.30	1.84	9.79	13,496	14,202	2.7455
May		5.43	....	....	8.85	2.02	9.36	13,343	14,109	2.7141
		2.10	16.72	69.35	11.83	1.57	12.08	13,379	13,666	2.6215
June		2.74	16.43	72.42	8.41	1.75	8.65	13,788	14,176	2.8253
		1.11	15.43	73.83	9.63	1.81	9.74	13,877	14,033	2.8236
Average		3.17	15.42	72.26	9.15	1.75	9.45	13,748	14,198	2.7971

PHILADELPHIA, PA., MINT BUILDING.

[Acme run of mine, Acme Slope mine, Hawk Run, Clearfield County, Pa.; 4,000 tons at $3.14; 7.8 per cent ash, 14,000 B. t. u.]

1908.										
July	49.080	2.03	17.30	73.30	7.37	2.32	7.52	14,158	14,457	$3.1754
August	159.627	2.17	18.66	71.24	7.93	2.16	8.10	14,170	14,485	3.1781
September	244.326	1.99	18.76	71.78	7.47	1.97	7.62	14,293	14,584	3.2057
October	289.094	2.38	22.56	67.38	7.68	2.27	7.86	14,156	14,497	3.1750
November	290.084	2.24	21.55	67.19	9.02	2.84	9.23	13,897	14,216	3.1169
December	330.263	2.68	21.74	67.29	8.29	2.55	8.52	14,005	14,377	3.1411
1909.										
January	346.303	2.93	20.80	67.89	8.38	2.28	8.63	13,940	14,359	3.1265
February	294.205	3.34	20.91	68.10	7.65	2.08	7.92	14,048	14,533	3.1508
March	355.344	2.65	21.20	68.83	7.32	1.84	7.52	14,104	14,488	3.1633
April	318.906	2.65	21.58	68.51	7.26	2.06	7.46	14,122	14,506	3.1674
May	309.009	2.27	21.40	68.82	7.51	1.88	7.69	14,060	14,386	3.1535
June	389.397	2.57	20.93	68.30	8.20	2.14	8.41	13,924	14,291	3.1230
Total	3,375.638									
Average		2.56	21.00	68.56	7.88	2.19	8.09	14,054	14,423	3.1520

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

ROCK ISLAND, ILL., ROCK ISLAND ARSENAL.

[Egg anthracite, 1,000 tons at $8.62; 6.72 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
August	175						13.12			
November	105						12.68			
December	140						12.18			
1909.										
February	70						13.48			
March	70						14.02			
April	210						13.94			
May	105						11.60			
Total	[a] 875									
Average							13.03			

[a] Deliveries amounted to 25 cars, estimated at 35 tons each.

ROCK ISLAND, ILL., ROCK ISLAND ARSENAL.

[Run of mine, 5,000 tons at $2.25; 13.2 per cent ash, 11,100 B. t. u.]

1908.										
August	140	13.92					17.53	10,141	11,781	$1.9856
September	105	13.82					18.32	10,037	11,646	1.9145
October	420	12.94					16.67	10.277	11,804	2.0432
November	210	14.17					18.18	10,017	11,671	1.9605
December	805	14.70					14.53	10,268	12,038	2.0814
1909.										
January	1,260	14.75					15.39	10,353	12,144	2.0786
February	490	15.35					14.28	10,328	12,201	2.0935
March	805	14.75					14.92	10,250	12,023	2.0777
April	175	13.84					13.74	10,615	12,320	2.1517
May	245	12.93					12.86	10,991	12,623	2.2279
June	245	13.67					14.48	10,461	12,117	2.1205
Total	[a] 4,900									
Average		14.40					15.18	10,333	12,071	2.0945

[a] Deliveries amount to 140 cars, estimated at 35 tons each.

SPRINGFIELD, MASS., SPRINGFIELD ARMORY.

[Imperial run of mine, Cambria County, Pa.; 5,000 tons at $4.15; 7 per cent ash, 14,000 B. t. u.]

1908.										
September		1.61					7.27	14,470	14,707	$4.2893
October		1.80					8.58	14,128	14,387	4.1879
December							9.61	14,068		4.1502
1909.										
March		3.48					14.41	12,796	13,257	3.5431
May		5.78					8.71	13,455	14,280	3.9884
July		1.70					7.82	14,150	14,394	4.1945
Average [a]		2.87					9.36	13,800	14,208	4.0707

[a] Average irrespective of monthly amounts delivered; month of December not included in average.

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

ST. LOUIS, MO., CUSTOM-HOUSE.

[Staunton lump, over 3" round-opening screen, No. 6 bed, Staunton mine No. 7, Staunton, Ill., 4,500 tons at $2.43; 12 per cent ash, 12,000 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	252.134	11.68	36.08	41.62	10.62	3.45	12.01	10,945	12,393	$2.2164
August	258.958	12.25	33.62	42.79	11.34	3.74	12.93	10,785	12,290	2.1840
September	328.741	9.65	34.34	43.13	12.88	3.99	14.26	10,979	12,152	2.2032
October	305.900	11.22	33.29	45.38	10.11	3.90	11.39	11,138	12,546	2.2554
November	270.636	10.31	36.33	41.40	11.96	3.80	13.33	10,931	12,191	2.2135
December	333.014	10.92	36.30	41.31	11.47	3.70	12.88	10,968	12,313	2.2210
1909.										
January	356.386	11.59	35.90	41.28	11.23	3.91	12.70	10,855	12,277	2.1981
February	283.083	11.65	35.87	41.27	11.21	3.83	12.69	10,867	12,300	2.2006
March	328.657	10.49	36.83	41.00	11.68	4.27	13.05	10,990	12,278	2.2255
April	294.164	11.83	38.09	38.53	11.55	3.38	13.11	10,780	12,226	2.1830
May	256.023	12.05	37.72	38.74	11.49	3.68	13.06	10,733	12,204	2.1734
June	200.134	12.26	37.29	40.36	10.09	3.82	11.50	10,763	12,266	2.1795
Total	3,467.830									
Average		11.29	35.95	41.41	11.35	3.80	12.79	10,903	12,291	2.2079

ST. PAUL, MINN., COURT-HOUSE AND POST-OFFICE.

[Youghiogheny gas lump, over 1" bar screen, thin vein, second pool, Budd mine, Westmoreland County, Pa.; 1,200 tons at $5.38; 8 per cent ash, 13,300 B. t. u.]

1908.										
July	143.701	2.18	35.88	56.44	5.50	1.46	5.62	14,139	14,454	$5.7394
November	166.307	2.13	33.99	56.78	7.10	1.59	7.25	13,889	14,189	5.6174
December	43.449	1.41	35.32	56.14	7.13	1.72	7.23	14,049	14,250	5.6830
1909.										
January	404.683	2.16	35.59	52.75	9.50	1.79	9.71	13,340	13,634	5.3962
April	245.426	2.04	34.25	55.81	7.90	1.85	8.06	13,668	13,953	5.5289
Total	1,003.566									
Average		2.10	35.02	54.84	8.04	1.72	8.21	13,655	13,948	5.5236

ST. PAUL, MINN., CUSTOM-HOUSE.

[Youghiogheny gas lump over 1" bar screen, thin vein, second pool, Budd mine, Westmoreland County, Pa.; 250 tons at $5.38; 8 per cent ash, 13,300 B. t. u.]

1908.										
July	28.08	1.96	35.47	57.86	4.71	1.11	4.80	14,342	14,629	$5.8315
November	29.133	2.46	35.37	56.28	5.89	1.54	6.04	13,835	14,184	5.6064
1909.										
January	42.209	3.07	34.50	56.75	5.68	1.03	5.86	13,865	14,304	5.6285
March	46.160	1.63	39.58	54.69	4.10	1.92	4.17	14,296	14,533	5.8129
April	12.321	1.80	35.00	56.71	6.49	1.71	6.61	14,035	14,292	5,6873
Total	157.903									
Average		2.24	36.36	56.25	5.15	1.45	5.27	14,084	14,407	5.7171

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

TOLEDO, OHIO, CUSTOM-HOUSE.

[Pocahontas run of mine, McDowell County, W. Va.; 500 tons at $3.95; 4.45 per cent ash, 14,900 B. t. u.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
August	7.526	3.71	14.03	78.13	4.13	0.65	4.29	14,569	15,130	$3.8623
September	51.785	2.51	14.06	78.61	4.82	.47	4.94	14,724	15,103	3.9033
November	39.772	2.09	16.60	76.44	4.87	.71	4.96	14,648	14,960	3.8832
December	45.167	2.65	19.66	74.06	3.63	.61	3.73	14,872	15,277	3.9426
1909.										
January	39.685	2.97	18.38	74.06	4.05	.58	4.18	14,730	15,181	3.9049
March	64.723	3.27	19.62	73.15	3.96	.92	4.09	14,729	15,227	3.9047
June	6.316	3.46	18.81	74.47	3.26	.51	3.38	14,610	15,134	3.8831
Total	254.974	....	....	....	....	....	....	....	....	....
Average	....	2.79	17.65	75.34	4.22	.67	4.34	14,734	15,157	3.9060

WASHINGTON, D. C., AGRICULTURE DEPARTMENT, MAIN BUILDING.

[Furnace [a] anthracite, at $5.72 per ton; 10 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. As received.	B. t. u. Dry coal.	Corrected price per ton.
1908.										
September	25	....	....	....	....	....	8.37	....	....	$5.72
October	50	....	....	....	....	....	11.14	....	....	5.72
November	50	....	....	....	....	....	12.06	....	....	5.57
	50	....	....	....	....	....	12.47	....	....	5.57
December	50	....	....	....	....	....	11.33	....	....	5.72
	75	....	....	....	....	....	12.78	....	....	5.54
	25	....	....	....	....	....	11.55	....	....	5.72
1909.										
January	75	....	....	....	....	....	11.87	....	....	5.72
	100	....	....	....	....	....	11.22	....	....	5.72
February	25	....	....	....	....	....	12.08	....	....	5.57
March	100	....	....	....	....	....	13.29	....	....	5.51
April	100	....	....	....	....	....	12.17	....	....	5.57
May	25	....	....	....	....	....	10.11	....	....	5.72
	25	....	....	....	....	....	10.65	....	....	5.72
Total	775	....	....	....	....	....	....	....	....	....
Average	....	....	....	....	....	....	11.85	....	....	5.72

[a] Contract provides for 3,600 tons of furnace anthracite, for main building and Weather Bureau.

WASHINGTON, D. C., AGRICULTURE DEPARTMENT, MAIN BUILDING.

[Egg anthracite; 20 tons at $6.88; 10 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. As received.	B. t. u. Dry coal.	Corrected price per ton.
1908.										
October	15	....	....	....	....	....	13	....	....	$6.70
December	30	....	....	....	....	....	12.63	....	....	6.70
Total	45	....	....	....	....	....	....	....	....	....
Average	....	....	....	....	....	....	12.75	....	....	6.70

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

WASHINGTON, D. C., AGRICULTURE DEPARTMENT, WEATHER BUREAU.

[Furnace[a] anthracite, at $5.72 per ton; 10 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
August	50	....	....	....	....	....	10.17	....	....	$5.72
October	50	....	....	....	....	....	10.14	....	....	5.72
November	50	....	....	....	....	....	11.21	....	....	5.72
December	50	....	....	....	....	....	11.69	....	....	5.72
1909.										
January	49.90	....	....	....	....	....	12.46	....	....	5.57
	50	....	....	....	....	....	9.39	....	....	5.72
February	50	....	....	....	....	....	9.64	....	....	5.72
March	49.86	....	....	....	....	....	10.48	....	....	5.72
	50.63	....	....	....	....	....	9.28	....	....	5.72
May	49.81	....	....	....	....	....	9.07	....	....	5.72
Total	500.20	....	....	....	....	....	....	....	....	....
Average	....	....	....	....	....	....	10.35	....	....	5.72

[a] Contract provides for 3,600 tons of furnace anthracite, for main building and Weather Bureau.

WASHINGTON, D. C., AGRICULTURE DEPARTMENT, WEATHER BUREAU.

[Stove[a] anthracite, at $6.92 per ton 10 per cent ash.]

1908.										
November	2	....	....	....	....	....	11.90	....	....	$6.92
1909.										
January	2	....	....	....	....	....	12.64	....	....	6.92
March	2	....	....	....	....	....	16.21	....	....	6.65
Total	6	....	....	....	....	....	....	....	....	....
Average	....	....	....	....	....	....	13.58	....	....	6.92

[a] Contract provides for 250 tons of stove anthracite, for main building and Weather Bureau.

WASHINGTON, D. C., CONGRESS, BOTANICAL GARDENS.

[Furnace anthracite, 350 tons at $5.59; 10 per cent ash.]

1908.										
November	50	....	....	....	....	....	10.81	....	....	$5.59
December	200	....	....	....	....	....	11.65	....	....	5.59
1909.										
March	50	....	....	....	....	....	10.40	....	....	5.59
April	25	....	....	....	....	....	8.87	....	....	5.59
Total	325	....	....	....	....	....	....	....	....	....
Average	....	....	....	....	....	....	11.11	....	....	5.59

WASHINGTON, D. C., CONGRESS, BOTANICAL GARDENS.

[Chestnut anthracite, 20 tons at $6.65; 14 per cent ash.]

1908.										
December	6	....	....	....	....	....	15.90	....	....	$6.65

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908-9*—Cont'd.

WASHINGTON, D. C., CONGRESS, GOVERNMENT PRINTING OFFICE.

[Egg anthracite, 9,000 tons at $5.78; 10 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	85						10.78			$5.78
August	500						11.19			5.78
September	500						10.21			5.78
October	500						11.13			5.78
November	500						10.77			5.78
December	500						9.90			5.78
	500						11.20			5.78
1909.										
January	500						12.03			5.63
	500						11.60			5.78
February	500						12.17			5.63
March	500						13.03			5.57
	500						12.64			5.60
April	500						12.33			5.63
	500						12.69			5.60
May	500						11.61			5.78
June	500						11.21			5.78
	500						11.82			5.78
Total	8,085									
Average							11.59			5.78

WASHINGTON, D. C., CONGRESS, LIBRARY OF CONGRESS.

[Furnace anthracite, 3,600 tons at $5.52; 10 per cent ash.]

1908.										
June	614						9.61			$5.52
July	468						9.69			5.52
August	546						9.61			5.52
November	429						9.35			5.52
December	445						9.84			5.52
1909.										
February	247						11.48			5.52
March	339						11.10			5.52
	292						10.72			5.52
	220						10.27			5.52
June	100						12.03			5.37
Total	3,700									
Average							10.07			5.52

WASHINGTON, D. C., INTERIOR DEPARTMENT, BUREAU OF EDUCATION.

[Furnace anthracite, 100 tons,at $5.85; 10 per cent ash.]

1908.										
October	20						10.73			$5.85
1909.										
January	20						11.65			5.85
March	20						9.29			5.85
Total	60									
Average							10.56			5.85

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908-9*—Cont'd.

WASHINGTON, D. C., INTERIOR DEPARTMENT, UNITED STATES CIVIL SERVICE COMMISSION.

[Furnace anthracite, 250 tons at $5.85; 10 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	10						7.88			$6.00
September	4.54						11.57			5.85
November	40						12.36			5.70
December	30						10.41			5.85
1909.										
January	30						10.20			5.85
February	30						13.05			5.64
March	30						11.78			5.85
April	20						11.92			5.85
June	20						10.49			5.85
Total	214.54									
Average							11.36			5.85

WASHINGTON, D. C., INTERIOR DEPARTMENT, FREEDMEN'S HOSPITAL.

[Egg anthracite, 50 tons at $6.45; 10 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	As received.	Dry coal.	Corrected price per ton.
1908.										
November	10						10.46			$6.45
1909.										
February	10						12.96			6.27
June	2						11.92			6.45
Total	22									
Average							11.73			6.45

WASHINGTON, D. C., INTERIOR DEPARTMENT, FREEDMEN'S HOSPITAL.

[Pea anthracite, 200 tons at $4.40; 14 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	As received.	Dry coal.	Corrected price per ton.
1908.										
September	25						13.73			$4.40

WASHINGTON, D. C., INTERIOR DEPARTMENT, FREEDMEN'S HOSPITAL AND HOWARD UNIVERSITY.

[Orenda run of mine, Boswell, Somerset County, Pa.; 900 tons at $3.55; 10 per cent ash, 13,900 B. t. u.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	As received.	Dry coal.	Corrected price per ton.
1908.										
September	50	2.20					9.24	14,021	14,339	$3.5809
October	75	1.96					8.68	14,041	14,323	3.5960
November	100	3.27					8.38	13,970	14,443	3.5779
	100	3.71					9.82	13,693	14,221	3.4971
	175	1.48					9.80	13,971	14,180	3.5681
December	150	2.72					9.14	13,919	14,309	3.5549
	150	3.07					8.42	13,969	14,412	3.5776
	100	2.90					8.98	13,854	14,267	3.5483
1909.										
January	150	2.81					9.36	13,807	14,210	3.5262
	100	2.14					8.77	14,016	14,322	3.5896
February	100	3.00					8.78	13,788	14,214	3.5314
	100	2.80					8.78	13,933	14,335	3.5684
	100	2.78					9.35	13,858	14,254	3.5393
March	200	2.84					9.30	13,750	14,152	3.5117
	150	2.62					8.89	13,881	14,253	3.5551
April	100	2.37					9.07	13,896	14,234	3.5490
May	100	3.05					8.86	13,725	14,157	3.5153
Total	2,000									
Average		2.68					9.07	13,879	14,262	3.5446

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908-9*—Cont'd.

WASHINGTON, D. C., INTERIOR DEPARTMENT, GOVERNMENT HOSPITAL FOR THE INSANE.

[Stove anthracite, 1,000 tons at $5.75; 12 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
November	350	....	....	....	....	....	12.02	....	....	$5.75
1909.										
March	350	....	....	....	....	....	14.12	....	....	5.60
April	105	....	....	....	....	....	14.49	....	....	5.60
Total	[a] 805	....	....	....	....	....	....	....	....	....
Average	....	....	....	....	....	....	13.25	....	....	5.75

[a] Deliveries amounted to 23 cars, estimated at 35 tons each.

WASHINGTON, D. C., INTERIOR DEPARTMENT, GOVERNMENT HOSPITAL FOR THE INSANE.

[Georges Creek run of mine, big vein, Tyson bed, 20,000 tons at $3.05; 7.5 per cent ash, 14,300 B. t. u.]

1908.										
August	315	3.34	....	....	....	....	6.98	14,248	14,740	$3.0389
September	910	2.44	....	....	....	....	7.21	14,357	14,716	3.0622
October	2,030	2.72	....	....	....	....	8.19	14,009	14,401	2.9879
November	875	2.41	....	....	....	....	8.15	14,052	14,398	2.9971
December	1,085	2.87	....	....	....	....	7.11	14,249	14,670	3.0391
1909.										
January	1,540	3.30	....	....	....	....	8.72	13,844	14,316	2.9527
February	1,505	3.23	....	....	....	....	7.55	14,049	14,518	2.9965
March	1,925	2.63	....	....	....	....	7.77	14,027	14,404	2.9918
April	1,855	2.70	....	....	....	....	7.83	13,698	14,076	2.9216
May	1,015	4.65	....	....	....	....	10.12	13,253	13,899	2.8067
June	525	3.57	....	....	....	....	9.16	13,568	14,071	2.8939
Total	[a] 13,580	....	....	....	....	....	....	....	....	....
Average	....	2.99	....	....	....	....	8.07	13,932	14,361	2.9715

[a] Deliveries amounted to 388 cars, estimated at 35 tons each.

WASHINGTON, D. C., INTERIOR DEPARTMENT, HOWARD UNIVERSITY.

[Furnace anthracite, 400 tons at $5.75; 8 per cent ash.]

1908.										
November	20	....	....	....	....	....	10.85	....	....	$5.57
1909.										
March	10	....	....	....	....	....	12.57	....	....	5.51
Total	30	....	....	....	....	....	....	....	....	....
Average	....	....	....	....	....	....	11.42	....	....	5.54

WASHINGTON, D. C., INTERIOR DEPARTMENT, HOWARD UNIVERSITY.

[Egg anthracite, 100 tons at $6.20; 8 per cent ash.]

1908.										
October	88	....	....	....	....	....	11.30	....	....	$5.99
1909.										
February	5	....	....	....	....	....	15.82	....	....	5.72
	10	....	....	....	....	....	11.41	....	....	5.99
Total	103	....	....	....	....	....	....	....	....	....
Average	....	....	....	....	....	....	11.61	....	....	5.96

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

WASHINGTON, D. C., INTERIOR DEPARTMENT, HOWARD UNIVERSITY.

[Stove anthracite, 50 tons at $6.65; 10 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
November	20						11.72			$6.65
1909.										
January	5						13.50			6.44
February	10						16.42			6.26
	5						11.10			6.65
March	5						15.02			6.32
Total	45									
Average							13.26			6.44

WASHINGTON, D. C., INTERIOR DEPARTMENT, LAND OFFICE.

[Georges Creek run of mine, big vein, Allegany County, Md., 3,600 tons at $3.65; 8 per cent ash, 14,200 B. t. u.]

1908.										
July	250	1.43					7.91	14,274	14,481	$3.6690
August	250	2.48					8.27	13,911	14,265	3.5757
September	300	1.95					7.76	14,333	14,617	3.6841
October	300	1.60					7.93	14,363	14,600	3.6919
November	300	1.75					7.36	14,367	14,622	3.6929
	300	1.28					7.81	14,395	14,582	3.7001
December	300	1.72					7.80	14,303	14,554	3.6765
1909.										
January	300	2.34					7.66	14,202	14,543	3.6505
February	300	1.79					7.39	14,337	14,597	3.6852
	300	2.06					7.76	14,241	14,540	3.6605
March	300	1.31					7.27	14,397	14,587	3.7006
April	300	1.32					7.37	14,344	14,543	3.6870
May	300	1.39					8.00	14,230	14,431	3.6577
June	100	1.91					7.10	14,255	14,532	3.6641
Total	3,900									
Average		1.72					7.69	14,289	14,539	3.6729

WASHINGTON, D. C., INTERIOR DEPARTMENT, PENSION OFFICE.

[Furnace anthracite, 1,200 tons at $5.85; 10 per cent ash.]

1908.										
July	50						11.13			$5.85
September	100						11.89			5.85
November	150						11.06			5.85
December	150						10.93			5.85
1909.										
January	150						11.34			5.85
February	100						11.86			5.85
April	100						11.10			5.85
Total	800									
Average							11.30			5.85

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908-9*—Cont'd.

WASHINGTON, D. C., INTERIOR DEPARTMENT, UNITED STATES GEOLOGICAL SURVEY.

[Furnace anthracite, 600 tons at $5.85; 10 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	15						11.01			$5.85
August	10						9.39			5.85
September	10						12.35			5.70
October	20						11.25			5.85
November	40						10.65			5.85
December	65						11.99			5.85
1909.										
January	101.78						11.84			5.85
February	100						11.76			5.85
April	50						11.87			5.85
May	20						10.61			5.85
July	10						12.45			5.70
Total	441.78									
Average							11.60			5.85

WASHINGTON, D. C., NAVY DEPARTMENT, UNITED STATES NAVAL OBSERVATORY.

[Furnace anthracite, 600 tons at $6.20; 10 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	As received.	Dry coal.	Corrected price per ton.
1908.										
August	144						11.09			$6.20
December	137.52						11.49			6.20
1909.										
January	106						13.97			5.96
February	106.11						14.97			5.90
March	57.66						11.19			6.20
Total	551.29									
Average							12.50			6.05

WASHINGTON, D. C., NAVY DEPARTMENT, MILLS BUILDING.

[No. 1 buckwheat anthracite, 500 tons at $3.70; 18 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	As received.	Dry coal.	Corrected price per ton.
1908.										
November	50						17.10			$3.70
December	75						16.22			3.76
1909.										
January	52						15.73			3.78
February	51.34						18.61			3.70
March	53.86						15.11			3.80
April	53						17.62			3.70
Total	335.20									
Average							16.68			3.74

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

WASHINGTON, D. C., POST-OFFICE DEPARTMENT, POST-OFFICE BUILDING.

[Pea anthracite, 6,000 tons at $4.35; 16 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	500						16.52			$4.35
October	500						15.22			4.35
November	500						15.71			4.35
December	500						14.69			4.40
1909.										
January	500						16.21			4.35
February	500						16.15			4.35
March	500						15.70			4.35
April	500						15.68			4.35
May	500						15.08			4.35
June	500						15.34			4.35
Total	5,000									
Average							15.63			4.35

WASHINGTON, D. C., SMITHSONIAN INSTITUTION, EMERY BUILDING.

[Egg anthracite, 80 tons at $6.29; 10 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. As received.	B. t. u. Dry coal.	Corrected price per ton.
1908.										
July	30						10.39			$6.29

WASHINGTON, D. C., SMITHSONIAN INSTITUTION, NATIONAL MUSEUM.

[Furnace anthracite, 1,200 tons at $5.74; 10 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. As received.	B. t. u. Dry coal.	Corrected price per ton.
1908.										
July	175						10.54			$5.74
November	100						10.69			5.74
December	100						11.06			5.74
1909.										
January	100						11.39			5.74
February	200						10.76			5.74
March	100						10.64			5.74
	50						10.04			5.74
May	25						10.83			5.74
Total	850									
Average							10.76			5.74

WASHINGTON, D. C., SMITHSONIAN INSTITUTION, NATIONAL ZOOLOGICAL PARK.

[Furnace anthracite, 1,200 tons at $6.88; 10 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. As received.	B. t. u. Dry coal.	Corrected price per ton.
1908.										
September	25						11.10			$6.88
1909.										
January	21.5						9.05			6.88
February	13						11.04			6.88
April	6						11.86			6.88
May	6						10.23			6.88
Total	71.5									
Average							10.46			6.88

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

WASHINGTON, D. C., SMITHSONIAN INSTITUTION, NATIONAL ZOOLOGICAL PARK.

[Stove anthracite, 30 tons at $7.48; 12 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
September	15						13.24			$7.48
1909.										
May	2						12.19			7.48
Total	17									
Average							13.12			7.48

WASHINGTON, D. C., SMITHSONIAN INSTITUTION, NATIONAL ZOOLOGICAL PARK.

[Chestnut anthracite, 30 tons at $7.48; 14 per cent ash.]

1908.										
September	5						15.44			$7.48
1909.										
March	4						21.13			7.03
Total	9									
Average							17.97			7.24

WASHINGTON, D. C., SMITHSONIAN INSTITUTION, NATIONAL ZOOLOGICAL PARK.

[Georges Creek run of mine, 300 tons at $4.38; 9 per cent ash.]

1908.										
July	100	2.26					7.71	14,283	14,613	$4.39
December	46.29	2.22					8.25	14,123	14,444	4.38
1909.										
January	54	3.01					7.51	14,144	14,583	4.39
February	100	2.54					7.48	14,124	14,492	4.39
Total	300.29									
Average		2.48					7.68	14,130	14,541	4.39

WASHINGTON, D. C., STATE DEPARTMENT, STATE STABLES.

[Stove anthracite, 12 tons at $6.88; 12 per cent ash.]

1908.										
November	4						13.27			$6.88
1909.										
January	4						13.45			6.88
April	1						16.06			6.61
Total	9									
Average							13.66			6.88

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908-9*—Cont'd.

WASHINGTON, D. C., STATE DEPARTMENT, STATE, WAR, AND NAVY BUILDING.

[No. 1 buckwheat anthracite, 4,500 tons at $3.7; 18 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	200						17.57			$3.70
August	213						18.95			3.70
October	400						18.80			3.79
November	508						17.02			3.70
December	500						16.83			3.74
1909.										
January	500						17.40			3.70
February	500						17.36			3.70
March	500						19.73			3.62
April	500						18.08			3.70
Total	3,816									
Average							17.91			3.70

WASHINGTON, D. C., TREASURY DEPARTMENT, BUREAU OF ENGRAVING AND PRINTING.

[New River run of mine, Sewell bed, Fayette and Raleigh counties, W. Va., Loup and Piney creeks, 8,000 tons at $3.35; 5.7 per cent ash; 14,600 B. t. u.]

1908.										
July	205.147	1.89	19.15	73.59	5.37	0.97	5.44	14,569	14,852	$3.3429
August	505.558	1.61	20.79	73.03	4.57	.95	4.64	14,822	15,064	3.4109
September	595.174	1.94	18.39	74.75	4.92	.94	5.02	14,691	14,981	3.3709
October	298.848	1.53	22.16	71.76	4.55	.98	4.62	14,792	15,022	3.4041
November	871.174	1.94	22.20	71.90	3.96	.82	4.04	14,850	15,143	3.4174
December	781.750	2.25	22.75	70.75	4.25	.71	4.36	14,619	14,961	3.3644
1909.										
January	869.112	2.01	22.71	71.13	4.15	.90	4.23	14,835	15,139	3.4139
February	434.665	1.76	22.01	72.53	3.70	.81	3.77	14,938	15,205	3.4376
March	862.089	1.76	23.55	70.65	4.04	.90	4.11	14,783	15,048	3.4020
April	536.701	3.33	22.10	70.63	3.94	.87	4.09	14,654	15,159	3.3724
	75.522	2.06	22.93	71.03	3.98	.91	4.06	14,691	15,000	3.3809
May	507.116	2.77	22.27	70.35	4.61	.97	4.74	14,469	14,883	3.3199
June	293.545	1.49	24.49	69.50	4.52	.68	4.59	14,707	14,929	3.3846
Total	6,836.401									
Average		2.06	22.06	71.60	4.28	.87	4.37	14,742	15,052	3.3926

WASHINGTON, D. C., TREASURY DEPARTMENT, TREASURY BUILDING.

[New River run of mine, Sewell bed, Fayette and Raleigh counties, W. Va., Loup and Piney creeks, 2,000 tons at $3.55; 5.7 per cent ash; 14,600 B. t. u.]

1908.										
July	204.344	3.37	15.33	77.28	4.02	0.84	4.16	14,507	15,013	$3.5374
October	100	2.21	21.37	71.77	4.65	.75	4.75	14,657	14,988	3.5639
December	200	2.72	22.46	70.87	3.95	.91	4.06	14,719	15,131	3.5889
1909.										
February	203.085	3.10	22.38	70.04	4.48	.87	4.62	14,544	15,009	3.5464
	50.242	5.97	21.26	68.70	4.07	1.13	4.33	14,135	15,032	3.4469
March	118.089	3.46	20.07	70.72	5.75	.72	5.96	14,502	15,022	3.5262
April	43.487	2.05	22.47	71.20	4.28	.90	4.37	14,669	14,976	3.5768
May	38.424	2.74	23.66	68.81	4.79	.73	4.92	14,428	14,834	3.5082
Total	957.671									
Average		3.12	20.50	71.95	4.43	.85	4.57	14,557	15,026	3.5495

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908-9*—Cont'd.

WASHINGTON, D. C., TREASURY DEPARTMENT, TREASURY BUILDING.

[Philadelphia and Reading rice anthracite, 1,500 tons at $3.35; 18 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	54.790	5.06	2.40	75.25	17.29	0.76	18.21	11,385	11,992	$3.35
August	145.594	4.27	3.00	74.07	18.66	.71	19.49	11,936	12,468	3.31
November	212.991	5.30	3.95	75.65	15.10	.56	15.95	11,687	12,341	3.43
December	35.125	6.19	2.92	75.75	15.14	.64	16.14	11,608	12,373	3.41
1909.										
January	172.665	5.26	5.70	72.37	16.67	.64	17.60	11,590	12,234	3.35
	51.071	5.51	5.58	64.82	24.09	.70	25.50	10,268	10,867	2.87
February	149.290	5.16	5.90	70.71	18.23	.70	19.22	11,287	11,901	3.31
March	103.514	4.30	5.56	71.93	18.21	1.07	19.03	11,498	12,015	3.31
	57.884	4.14	5.27	70.33	20.26	.89	21.13	11,132	11,613	3.03
April	115.429	3.60	6.26	68.52	21.61	1.10	22.42	11,447	11,875	2.87
May	114.746	7.21	5.88	67.75	19.16	.71	20.65	10,772	11,609	3.14
June	51.223	5.51	7.13	64.55	22.81	.79	24.14	10,358	10,962	2.87
Total	1,264.322									
Average		5.07	4.99	71.58	18.32	.75	19.30	11,382	11,989	3.35

WASHINGTON, D. C., TREASURY DEPARTMENT, WINDER BUILDING.

[New River run of mine, Sewell bed, Fayette and Raleigh counties, W. Va., Loup and Piney creeks, 400 tons at $3.60; 5.7 per cent ash; 14,600 B. t. u.]

1908.										
October	18.942	1.32	20.23	74.34	4.11	0.79	4.17	14,797	14,995	$3.6587
November	31.058	3.01	22.36	67.95	6.68	.89	6.89	14,220	14,661	3.5063
December	50.058	1.95	20.97	71.05	6.03	.90	6.15	14,611	14,902	3.6027
1909.										
January	67.576	3.18	22.39	70.11	4.32	1.00	4.46	14,508	14,984	3.5773
February	27.741	3.69	22.94	69.94	3.43	.51	3.56	14,633	15,194	3.6281
March	32.705	3.54	22.44	68.53	5.49	1.14	5.68	14,231	14,753	3.5090
April	39.067	2.24	22.04	70.62	5.10	.78	5.22	14,438	14,769	3.5601
May	10.933	3.69	24.26	66.99	5.06	.88	5.25	14,243	14,789	3.5120
Total	278.080									
Average		2.79	22.06	70.09	5.06	.89	5.20	14,466	14,882	3.5670

WASHINGTON, D. C., WAR DEPARTMENT.[a]

FURNACE ANTHRACITE, ARMY MEDICAL MUSEUM.

1908.										
July	86						9.36			$5.74
October	39						8.95			5.74
1909.										
February	75						11.64			5.74
April	25						10.97			5.74
Total	225									
Average							10.23			5.74

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[a] The War Department contract provides for anthracite coal as follows: Furnace, 400 tons at $5.74, 10 per cent ash; egg, 450 tons at $6.29, 10 per cent ash; stove, 375 tons at $6.49, 12 per cent ash; chestnut, 20 tons at $6.49, 14 per cent ash. To supply the following buildings: Army Medical Museum; buildings at 1725 and 1800 F street NW.; Ford Building; buildings at 1712 and 1744 G street NW.; Lemon Building; and War Department stables.

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

WASHINGTON, D. C., WAR DEPARTMENT—Continued.

EGG ANTHRACITE, 1725 F STREET NW.

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
July	18						9.90			$6.29
December	15						11.52			6.29
1909.										
February	10						11.50			6.29
March	5						10.44			6.29
Total	48									
Average							10.80			6.29

EGG ANTHRACITE, 1800 F STREET NW.

1908.										
July	20						10.46			$6.29
1909.										
January	18						10.47			6.29
March	5						9.60			6.29
April	1						11.18			6.29
Total	44									
Average							10.38			6.29

STOVE ANTHRACITE, 1800 F STREET NW.

1908.										
October	3						10.65			$6.49
1909.										
January	3						10.08			6.49
Total	6									
Average							10.37			6.49

STOVE ANTHRACITE, FORD BUILDING.

1908.										
July	100						11.57			$6.49
November	100						11.56			6.49
1909.										
February	100						13.91			6.49
April	50						14.31			6.34
Total	350									
Average							12.63			6.49

EGG ANTHRACITE, 1712 G STREET NW.

1908.										
July	3						18.73			$6.29
December	3						10.32			6.29
1909.										
January	3						12.59			6.11
February	3						13.49			6.08
March	2						10.58			6.29
Total	14									
Average							11.18			6.29

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908–9*—Cont'd.

WASHINGTON, D. C., WAR DEPARTMENT—Continued.

CHESTNUT ANTHRACITE, 1712 G STREET NW.

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
August	2						11.43			$6.67
1909.										
February	2						12.49			6.49
Total	4									
Average							11.96			6.64

EGG ANTHRACITE, 1744 G STREET NW.

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. as received.	B. t. u. dry coal.	Corrected price per ton.
1908.										
July	32						10.81			$6.29
1909.										
January	15						13.47			6.08
February	15						10.29			6.29
March	5						10.92			6.29
April	5						10.45			6.29
Total	72									
Average							11.24			6.29

EGG ANTHRACITE, LEMON BUILDING.

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. as received.	B. t. u. dry coal.	Corrected price per ton.
1908.										
July	10						11.30			$6.29
August	35						9.93			6.29
September	20						11.64			6.29
October	25						10.51			6.29
November	15						8.99			6.29
December	15						11.80			6.29
	15						10.93			6.29
1909.										
January	15						10.49			6.29
	15						11.87			6.29
	15						12.17			6.14
February	15						10.39			6.29
	15						9.60			6.29
March	15						11.14			6.29
	15						9.90			6.29
April	15						12.57			6.11
May	15						12.44			6.11
June	10						9.87			6.29
Total	280									
Average							10.85			6.29

EGG ANTHRACITE, WAR DEPARTMENT STABLES.

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. as received.	B. t. u. dry coal.	Corrected price per ton.
1908.										
July	20						9.92			$6.29

STOVE ANTHRACITE, WAR DEPARTMENT STABLES.

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. as received.	B. t. u. dry coal.	Corrected price per ton.
1908.										
July	10						11.50			$6.49

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908-9*—Cont'd.

WASHINGTON, D. C., WAR DEPARTMENT, ISTHMIAN CANAL COMMISSION.

[Furnace anthracite, 125 tons at $5.80, 10 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
August	15						8.51			$5.80
December	25						10.43			5.80
1909.										
January	25						11.68			5.80
	25						10.54			5.80
March	25						9.22			5.80
May	25						10.42			5.80
Total	140									
Average							10.25			5.80

WASHINGTON, D. C., WAR DEPARTMENT, UNITED STATES SOLDIERS' HOME.

[Furnace anthracite, 460 tons at $5.95; 10 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. As received.	B. t. u. Dry coal.	Corrected price per ton.
1908.										
November	64.00						9.87			$5.95
1909.										
January	109.53						9.95			5.95
February	81.15						10.29			5.95
March	109.79						10.70			5.95
Total	364.47									
Average							10.24			5.95

WASHINGTON, D. C., WAR DEPARTMENT, UNITED STATES SOLDIERS' HOME.

[Stove anthracite, 350 tons at $6.75; 12 per cent ash.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. As received.	B. t. u. Dry coal.	Corrected price per ton.
1908.										
November	107.00						16.08			$6.48
1909.										
January	51.82						10.71			6.75
March	24.21						13.57			6.75
	43.32						13.94			6.75
	61.99						12.66			6.75
Total	288.34									
Average							13.85			6.75

WASHINGTON, D. C., WAR DEPARTMENT, UNITED STATES SOLDIERS' HOME.

[Orenda run of mine, C' bed, Boswell, Somerset County, Pa., 5,600 tons at $3.58 and $3.29;[a] 6 per cent ash, 14,300 B. t. u.]

Date.	Tons delivered.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Ash in dry coal.	B. t. u. As received.	B. t. u. Dry coal.	Corrected price per ton.
1908.										
July	251.43	2.45					8.86	14,034	14,386	$3.4934
August	261.17	2.39					9.14	13,970	14,312	3.4573
October	300.03	1.97					9.01	14,032	14,311	3.4729
November	568.86	1.94					9.50	13,981	14,257	3.4601
December	584.21	2.91					8.51	13,935	14,351	3.4686
	[b]221.80	2.91					8.51	13,935	14,351	3.1860
1909.										
January	714.85	2.44					9.31	13,926	14,274	3.1640
February	647.45	2.71					8.44	14,010	14,400	3.2033
March	728.44	3.11					9.98	13,662	14,101	3.1032
April	896.24	2.85					8.72	13,893	14,301	3.1764
May	345.92	2.68					8.35	13,913	14,296	3.1810
June	263.57	2.02					8.37	13,988	14,275	3.1982
Total	5,783.97									
Average		2.60					8.97	13,918	14,289	

[a] Price per ton: July 1 to December 31, 1908, $3.58; January 1 to June, 1909, $3.29.
[b] Payment based on January price per ton.

TABLE 8.—*Analyses of coals delivered to the Government under contracts, 1908-9*—Cont'd.

WATERTOWN, MASS., WATERTOWN ARSENAL.

[Furnace anthracite, "D. & H." Plymouth mine, Lehigh bed, 300 tons at $5.70; 10 per cent ash.]

Date.	Tons delivered.	Proximate analysis, as received.					Ash in dry coal.	B. t. u.		Corrected price per ton.
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.		As received.	Dry coal.	
1908.										
August	70	4.17					11.86	12,799	13,356	$5.70
November	35	4.07					10.39	12,878	13,424	5.70
December	105						12.84			5.52
1909.										
March	70	4.75					10.09	12,936	13,581	5.70
April	70	3.76					12.86	12,723	13,220	5.52
June	105	3.17					12.17	12,657	13,071	5.55
Total	[a] 455									
Average		3.89					11.65	12,777	13,294	[b] 5.70

[a] Deliveries amounted to 13 cars, estimated at 35 tons each.
[b] Month of December not included in average.

WATERTOWN, MASS., WATERTOWN ARSENAL.

[Orenda run of mine, C' bed, Boswell, Somerset County, Pa., 4,000 tons at $4.21; 8 per cent ash, 14,300 B. t. u.]

1908.										
August		2.57					9.11	13,977	14,345	$4.1149
October		2.96					8.52	14,009	14,436	4.1243
November		2.82					9.38	13,813	14,214	4.0666
December							10.82	13,420		3.9909
1909.										
January		2.40					9.16	13,483	13,815	3.9695
February		3.00					8.66	13,840	14,268	4.0746
March		3.25					10.13	13,576	14,032	3.9768
June		2.28					9.70	13,695	14,015	4.0319
Averages[a]		2.75					9.24	13,770	14,160	4.0540

[a] Averages irrespective of monthly amounts delivered; month of December not included in average.

SURVEY PUBLICATIONS ON FUEL TESTING.

The following publications, except those to which a price is affixed, can be obtained free by applying to the Director, Geological Survey, Washington, D. C. The priced publications can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

BULLETIN 261. Preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, in St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1905. 172 pp. 10 cents.

PROFESSIONAL PAPER 48. Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1906. In three parts. 1492 pp. $1.50.

BULLETIN 290. Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905, by J. A. Holmes. 1906. 240 pp. 20 cents.

BULLETIN 316. Contributions to economic geology, 1906, part 2, by M. R. Campbell and others. 1907. 543 pp. 70 cents.

BULLETIN 323. Experimental work conducted in the chemical laboratory of the United States fuel-testing plant at St. Louis, Mo., January 1, 1905, to July 31, 1906, by N. W. Lord. 1907. 49 pp. 10 cents.

BULLETIN 325. A study of four hundred steaming tests, made at the fuel-testing plant, St. Louis, Mo., 1904–1906, by L. P. Breckenridge. 1907. 196 pp. 10 cents.

BULLETIN 332. Report of the United States fuel-testing plant at St. Louis, Mo., January 1, 1906, to June 30, 1907; J. A. Holmes, in charge. 1908. 299 pp.

BULLETIN 334. The burning of coal without smoke in boiler plants; a preliminary report, by D. T. Randall. 1908. 26 pp. 5 cents. (See Bulletin 373.)

BULLETIN 336. Washing and coking tests of coal and cupola tests of coke, by Richard Moldenke, A. W. Belden, and G. R. Delamater. 1908. 76 pp. 10 cents.

BULLETIN 339. The purchase of coal under government and commercial specifications on the basis of its heating value, with analyses of coal delivered under government contracts, by D. T. Randall. 1908. 27 pp. 5 cents. (See Bulletin 378.)

BULLETIN 343. Binders for coal briquets, by J. E. Mills. 1908. 56 pp.

BULLETIN 362. Mine sampling and chemical analyses of coals tested at the United States fuel-testing plant, Norfolk, Va., in 1907, by J. S. Burrows. 1908. 23 pp. 5 cents.

BULLETIN 363. Comparative tests of run-of-mine and briquetted coal on locomotives, including torpedo-boat tests and some foreign specifications for briquetted fuel, by W. F. M. Goss. 1908. 57 pp.

BULLETIN 366. Tests of coal and briquets as fuel for house-heating boilers, by D. T. Randall. 1908. 44 pp.

BULLETIN 367. Significance of drafts in steam-boiler practice, by W. T. Ray and Henry Kreisinger. 1909. 61 pp.

BULLETIN 368. Washing and coking tests of coal at Denver, Colo., by A. W. Belden, G. R. Delamater, and J. W. Groves. 1909. 54 pp.

BULLETIN 373. The smokeless combustion of coal in boiler plants, by D. T. Randall and H. W. Weeks. 1909. 188 pp.

BULLETIN 378. Results of purchasing coal under government specifications, by J. S. Burrows; Burning the small sizes of anthracite for heat and power purposes, by D. T. Randall. 1909. 44 pp.

BULLETIN 385. Briquetting tests at Norfolk, Va., by C. L. Wright. 1909. 41 pp.

BULLETIN 392. Commercial deductions from comparisons of gasoline and alcohol tests on internal-combustion engines, by R. M. Strong. 1909. 38 pp.

BULLETIN 393. Incidental problems in gas-producer tests, by R. H. Fernald, C. D. Smith, J. K. Clement, and H. A. Grine. 1909. 29 pp.

BULLETIN 402. The utilization of fuel in locomotive practice, by W. F. M. Goss. 1909. 28 pp.

BULLETIN 403. Comparative tests of run-of-mine and briquetted coal on the torpedo boat *Biddle*, by W. T. Ray and Henry Kreisinger. 1909. 49 pp.

BULLETIN 412. Comparative tests of run-of-mine and briquetted coal on a locomotive boiler, by W. T. Ray and Henry Kreisinger. 1909. 32 pp.

BULLETIN 416. Recent development of the producer-gas power plant in the United States, by R. H. Fernald. 1909. 82 pp.

MINERAL RESOURCES, 1907. Coal briquetting in 1907, by E. W. Parker. pp. 223–228.

MINERAL RESOURCES, 1908. Coal briquetting in 1908, by E. W. Parker. Pt. 2, pp. 213–221.

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 429

OIL AND GAS IN LOUISIANA

WITH

A BRIEF SUMMARY OF THEIR OCCURRENCE IN ADJACENT STATES

BY

G. D. HARRIS

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OIL AND GAS IN LOUISIANA, WITH A BRIEF SUMMARY OF THEIR OCCURRENCE IN ADJACENT STATES.

By G. D. HARRIS.

INTRODUCTION.

During the last eleven years the Louisiana Geological Survey, in the course of its geologic work, has been gathering facts concerning the occurrence of oil and gas in Louisiana, and has published an elaborate report regarding the occurrence of salt within the State, which necessarily brought out many facts relating to oil and gas, the common if not universal accompaniments of saline deposits. During this interval the United States Geological Survey has published two reports relating in part to the oil of the State.[a]

It seemed therefore eminently proper, when field work was resumed by the State Survey in the fall of 1908, to devote the funds made available by the last legislature to the completion of an up-to-date report on the oil and gas resources of Louisiana. The United States Geological Survey added $1,500 to the State appropriation. The late fall and early winter of 1908 were spent in field work by G. D. Harris, I. Perrine, and W. E. Hopper. The laboratory or office work connected with this report has been done for the most part gratuitously.

OUTLINE OF OCCURRENCE, EXPLOITATION, AND RESULTS.

THE TWO MODES OF OCCURRENCE.

The expensive, avoidable mistakes thus far made in oil and gas development in Louisiana and adjacent States have been due mainly to a lack of proper understanding of the two very distinct ways in which these substances occur in this region. One way is well exemplified at Spindletop, a saline dome, where oil and gas have been highly concentrated in enormous quantities, all the surrounding territory being barren. The other way is equally well exemplified at Caddo or Corsicana, where oil and gas are coextensive with certain widespread, well-known geologic strata, though occurring in commercial quantities only in areas where the structure is favorable.

The importance of a clear understanding of the distinction here implied can scarcely be overestimated. A well sunk but a mile from the center of operations on a saline dome is sure to be a failure; a well 2, 4, or even 10 miles away from producers in fields where oil and gas occur at certain geologic horizons may be entirely successful. In the saline domes, where impervious layers overlie the oil-bearing beds, enormous yields from single wells have been obtained, reaching 10,000 barrels or more a day for months; in the fields of broadly expanded oil strata a 1,000-barrel well is a rarity.

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[a] Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: Bull. U. S. Geol. Survey No. 212, 1903. Fenneman, N. M., Oil fields of the Texas-Louisiana Gulf Coastal Plain: Bull. U. S. Geol. Survey No. 282, 1906.

In the present report the brief terms "saline dome" and "stratum" will be used to indicate these two modes of occurrence.

Since 1859 geologists and well operators have been accumulating knowledge regarding the geologic occurrence of stratum oil and gas; formation after formation has been added to the "productive" list till now it includes beds that range in age from Ordovician to Recent. Certain classes of oil and gas are expected from certain beds or horizons in Pennsylvania, West Virginia, and so on. In the Appalachian region the driller has learned to be on the lookout for the Big Injun, Squaw, or Cow Run sands and for the Clinton, Trenton, and other characteristic formations.

Saline-dome oil has been known in commercial quantities along the Gulf border only since 1901. Its composition may or may not vary, but has no relation to the particular stratum in which it is found. It occurs now where it stopped in its last migration, in beds ranging from Cretaceous to Quaternary, inclusive. The porous limestone and the overlying sands beneath Spindletop, all of which are oil bearing, are of Quaternary age. At Sour Lake oil has long been known at the surface and in Quaternary beds, and fossils prove that some oil comes from Oligocene and some from Eocene (Jackson) sands. In the Jennings field two sands at the same depth and apparently yielding oil from the same source are of Quaternary and Miocene age, though laterally but a few yards apart. Stratum oil or gas may have originated in the stratum where it is now found; saline-dome oil and gas are certainly migrants.

SALINE-DOME OIL AND GAS.

SALINE DOMES.[a]

GEOLOGY OF THEIR SURROUNDINGS.

In a broad way the geology of the lower Mississippi region is very simple. The early Eocene Mississippi embayment extended from the region of the present Gulf border, where it was 200 miles or more wide, to an apex at Cairo, Ill. To the northeast and the northwest Cretaceous rocks formed the border lands. From that time till this the great delta region has, on the whole, been filling in Gulfward. The result is that as the traveler passes from the Cretaceous rocks

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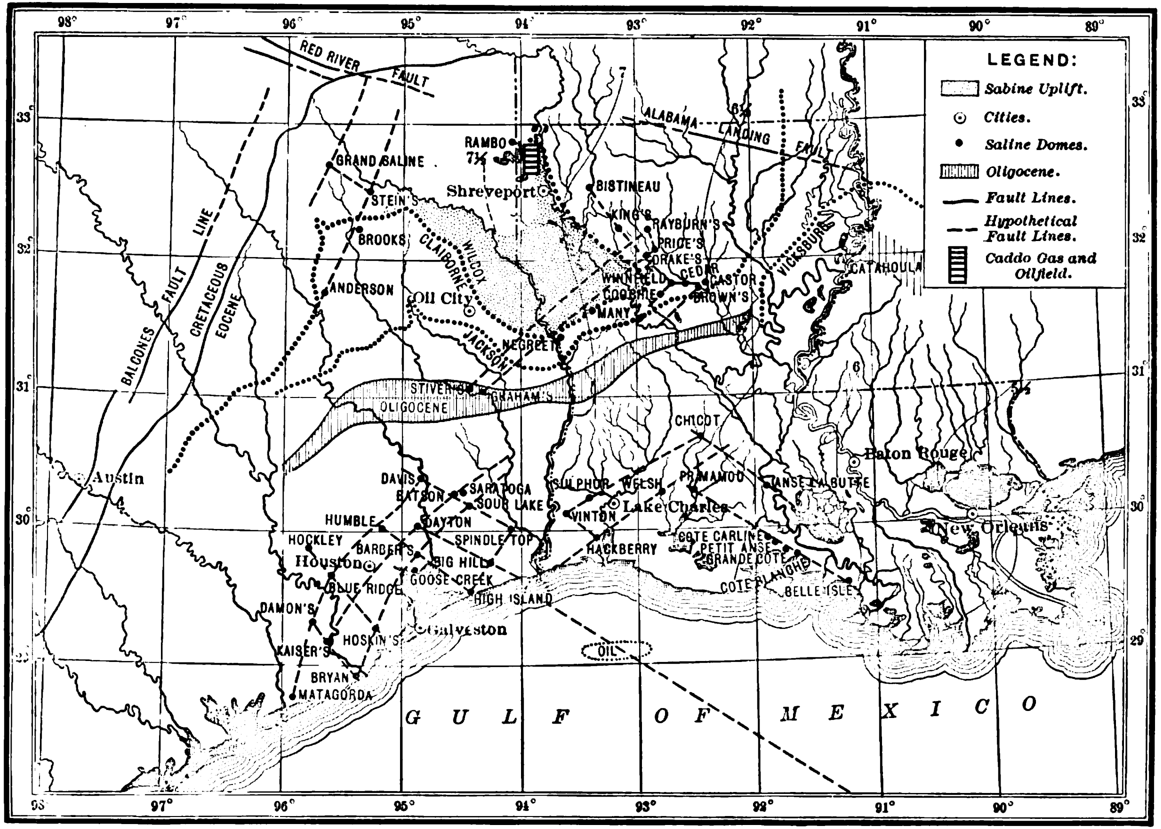
[a] For a discussion of the origin, history, and structure of saline domes, see Bull. Louisiana Geol. Survey No. 7, 1908, pp. 75 et seq.; Econ. Geology, vol. 4, 1909, pp. 12–34.



SKETCH MAP OF LOUISIANA AND EASTERN TEXAS, SHOWING MAIN STRUCTURAL FEATURES, ESPECIALLY THE SABINE UPLIFT AND THE SALINE DOMES AND THEIR PROBABLE INTERRELATIONSHIP.

southward he finds younger and younger rocks at the surface; in other words, the Cretaceous and Tertiary rocks lie deeper and deeper as the Gulf is approached.

This simple, broad conception must be somewhat modified to fit the conditions now existing in this region. Crustal movements have produced faults and displacements, as may be noted most clearly along the Balcones fault line and the Sabine uplift, as depicted on Plate I. The domes themselves appear to be situated at the junction of fault lines. The Tertiary beds along the Gulf border, though for the most part 2,000 feet below the surface, may on the flanks of these local domes lie at depths of only 600 feet or perhaps even less. It is not intended to suggest that this near approach to the surface of the usually deep-lying Tertiary rocks is due to anticlinal or quaquaversal structure brought about solely by crustal movements of the general type just referred to. But for reasons that have been stated in full in the papers already cited and are referred to briefly in the present report, it is evident that the domes are located at places of weakness brought about by crust-fracturing stresses. The domes should, therefore, correspond in alignment with the broad structural features of the region. Moreover, where their dimensions are great, indicating the accumulation and concentration of salts and hydrocarbons from vast areas, it is natural to expect that they will be separated from one another by broad stretches of undisturbed, unfractured, undomed territory.

COMPOSITION.

The nuclei of such domes as have already been penetrated sufficiently deep to admit of a decisive determination are pretty generally found to be made up of solid, crystalline rock salt. The lateral extent of a nucleus may be from a few yards to a mile and a half, and the thickness 1,000, 2,000, or perhaps many thousand feet. The apex of the salt may be slightly above sea level, as at Petite Anse; slightly below sea level, as at Grande Cote; some distance below, showing truncation by near-surface water, as at Anse la Butte; or far below, as at Spindletop, where it is well protected from erosion and solution by surface waters not only by a thick, calcareous oil-bearing layer, but by 1,000 feet of clay and sand. Anhydrite is common, here and there, more or less intercalated in the salt masses in the domes, as at Belle Isle, but generally in great bodies by itself. Crystalline cavernous limestone, clearly a secondary formation, without traces of fossils and of very small lateral extent, is a common dome material. At Spindletop it approaches within 1,000 feet of the surface; at Pine Prairie and at the "marble" quarry just west of Winnfield it is well exposed in surface outcrops. Gypsum is a common dome material, and native sulphur is often found in minor quantities. In one or two places pure sulphur in important masses alternates with gypsum.

THE DOMES IDEAL STRUCTURES FOR CONCENTRATING OIL AND GAS.

As the above-mentioned substances have crystallized from warm supersaturated solutions, crystalline growth has exerted an almost irresistible force that has bulged up all superjacent beds in these peculiar domelike forms. The reasons for the writer's belief in this mode of origin of these structures have been given in the papers above cited.[a] The important point in the present discussion is the excellent character of the structure for concentrating oil and gas. The oil or gas may have collected in a concavo-convex porous crystalline limestone capping of the saline nucleus, as at Spindletop. This is the bed that furnished the gusher production. Some oil may travel upward into pervious sands and there be held by overlying clays. The shallower "sands" at Spindletop and all the "sands" at Jennings are of this type. Again, the oil may be entrapped as it ascends in a porous stratum that has been tilted up and pinched out by the upward movement of the saline plug. Anse la Butte is an excellent example of this type of occurrence. In some places the saline plug is not overlain by pervious or impervious layers and neither oil nor gas is now to be found near it. Grande Cote, Petite Anse, and Cote Carline are good examples of such barren domes.

DOME ALIGNMENT.

As oil and gas occur in southern Louisiana and southeastern Texas in commercial quantities in the vicinity of saline domes a few hundred acres in extent, most of such localities being separated by barren regions scores of miles wide, it is highly important for future development that the manner of occurrence of these salines should be carefully studied, so that probably productive territory may be separated from territory in which the discovery of oil or gas is unlikely. In the effort to hit upon the right 40 acres in a parish of many hundred square miles where there is no good reason for supposing that oil exists there is one chance of success to several thousand of failure.

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[a] As a matter of scientific interest it may here be mentioned that there is no need for supposing that the high temperatures postulated for the saline solutions are due to the propinquity of molten rocks. The saline beds are undoubtedly very deeply buried and have normally a temperature sufficiently high to account for all the warmth required in dome building. No surface rock nor deep borings from these domes have ever shown the slightest trace of volcanic rocks. Nor do the domes produce local variations in terrestrial magnetic forces, as do the foci of volcanic activity generally. However, no one can seriously doubt that a laccolith may cause such dome structure in the overlying beds as to aid materially in the concentration of various hydrocarbons. That basaltic cores or plugs may perform the function of saline masses may be readily conceived. In fact such phenomena have been observed in Mexico, as indicated in the following communication to the Oil Investors' Journal (April 6, 1909, pp. 31-32): "The formation in the northern part of Vera Cruz and lower Tamaulipas is entirely different from that on the Isthmus. The surface consists of immense shale beds lying almost level. Below these shale beds is a calcareous marl several hundred feet thick. These marl beds are laminated, being hard and soft, with streaks as hard as a Trenton rock. What oil has been found so far has been found in soft streaks in the marl. Scattered over the country there are protruding out of the shale many sugar-loaf dikes of basalt, generally a hundred feet high or so. Immense seepages of asphalt are found at the base of these dikes. On account of the igneous character of these dikes geologists for a number of years refused to believe that oil in any quantity would be found in the territory. It now looks as if these dikes were pushed up during seismic disturbances which occurred after the formation of the oil beds. The only wells found of any consequence in the territory referred to have been located near the base of these basaltic dikes. It would seem, therefore, that the mother bed of the oil is at a much greater depth than any well has ever reached and that the oil produced is that which has escaped up alongside the dikes and worked itself out in lateral crevices. These lateral crevices furnish the oil. As there are many seepages scattered through the country where there are no protruding dikes, it is reasonable to suppose that the dikes exist but do not come near enough the surface to show themselves."

It may be suggested that the buried dikes referred to in this note could probably be located by a careful magnetic survey.

Though the available information may never be sufficiently complete to insure accuracy in the location of oil pools in advance of actual drilling in these coastal regions, it is believed that much help may be derived from a careful inspection of the main structural features of the lower Mississippi region, already briefly outlined. This great delta-shaped area, bordered on the east and west by the Cretaceous-Tertiary contact line and on the south by the Gulf, is characterized by northeast-southwest and northwest-southeast structural features, as indicated on Plate I. To suppose for an instant that the orderly rectilinear mode of occurrence of the saline domes is merely the work of chance is extreme folly. That the Sabine uplift has the general form indicated on Plate I is indicated by irregularities in forces of terrestrial magnetism, by the clearest kind of paleontologic evidence, and by direct stratigraphic proof. The Balcones fault line and the Red River faults are at the surface, can be seen, and admit of no question as to their existence. The Jennings and Five Island low anticline makes itself felt in the position of the submarine contour lines in the Gulf; the lower reaches of the Mississippi turn to the southeast above Baton Rouge and follow a synclinal depression to the Gulf. The oil pools in the Gulf platted by the Hydrographic Office show a parallel arrangement. Clearly, the varied wrenching and warping suffered by the rocks of this great delta region have given rise—and naturally so—to structural features more or less parallel to the shores of the old Cretaceous terranes to the northeast and northwest. In the opinion of the writer all the saline domes are located along lines of fracture in the deep-lying Mesozoic and Paleozoic rocks, and in general their location seems to be at the crossing of such lines. Prospecting for new fields should, it is believed, be carried on with a due consideration of these facts.

PROSPECTING IN AND AROUND SALINE DOMES.

From the nature or composition and the structure of saline domes as outlined above important deductions can be made as to the proper method of exploiting them for oil and gas. The sinking of a well into a salt nucleus whose upper termination is at or close to the surface of the ground may have the interesting though unprofitable result of showing the astonishing vertical dimensions of such nuclei, but even mere crevices in them containing oil and gas "showings" are likely to be rare. Such unsuccessful wells have been drilled at Goldonna, Anse la Butte, Petite Anse, Belle Isle, and other localities.

If the saline nucleus in its upward movement has pierced, bent up, and turned aside pervious and impervious strata of whatever age, from Cretaceous to Quaternary, inclusive, that have never contained hydrocarbons in any form, the resultant domes can not be expected to yield oil or gas. The large salt "islands" near the coast, and perhaps many of the saline domes in northern Louisiana and northeastern Texas, may prove to be of this type.

If the salt nucleus, though approaching the surface centrally, has at depths of several hundred or even a thousand feet or more passed through pervious and impervious layers, some of which contain hydrocarbons, the chances are that the upbended margins of the pervious layers next to the rising salt nucleus will be so sealed or compressed as to produce local pockets wherein oil and gas may collect. Anse la Butte is an excellent example of this type; Pine Prairie, Goldonna, Winnfield, and Coochie very likely fall into this category also. After a saline nucleus has been brought up near enough to the surface to be subjected to extensive underground flows of fresh water, more or less of the saline matter may be removed by solution, and accumulations of oil and gas may be set free and lost forever. Clearly, the proper manner of testing such saline domes for oil and gas is not by wasting money in a deep salt hole centrally located, but by searching for local pockets just outside the gas indications or circle of brine springs so common about these domes. Where the nucleus of a dome is volcanic matter, as described in the footnote on page 8, no one would think of drilling in the igneous mass. Then why should one drill in a salt nucleus? The supposed reason for the enterprise is not difficult to see. It rests wholly on a preconceived erroneous idea as to the origin and nature of the salt masses. They have been looked upon as kinks, sharp anticlines, or quaquaversals protruding upward from some widely extended salt sheet, and it is natural to suppose that under such structures oil and gas may be found. It has been stated in the papers already cited that in all probability the lower layers of the saline nuclei are far from anticlinal in structure—in fact, that they are very likely synclinal. The hope of obtaining a large supply of oil or gas by penetrating the Gulf coast salt domes can, in the writer's opinion, never be realized. As already remarked (p. 8), if the saline nucleus is many feet beneath the surface—say 1,000 feet, as at Spindletop, or at an unknown greater depth, as at Jennings—and if between these depths and the surface there are pervious layers overlain by extensive impervious layers, the conditions are favorable for the collection of oil and gas, particularly at or near the apex of the dome, where they are obtained easily and in immense quantities. The heavy gravity of the oil in such domes may perhaps be explained by its proximity to the surface and consequent loss of more volatile matter. This fact, taken in connection with the known mode of occurrence of oil in deep-lying lateral pockets about salt domes, as at Anse la Butte, points to the possibility of obtaining a very much higher grade of oil at great depths around the periphery of such fields as Spindletop. Quite naturally, salt water would be the material found in most of such test wells, yet there is no reason why good quantities of superior oil may not be hopefully looked for.

A further word must be said in connection with exploitation about saline domes. Scores of wells have been sunk "near" certain oil-producing domes in the groundless hope that somehow the influence of the domes might extend for several miles in every direction. Here, too, the real origin and extremely local nature of dome structure has been entirely overlooked. It is true that where the focus of disturbance is very deep seated and extensive, giving rise, as in the Jennings field, to a fault line perhaps half a mile in length, and where the impervious layers are not extensively developed, the oil and gas ascending through the fault fissure may spread out in many directions in certain "sands" for half or three-quarters of a mile, or perhaps even more. This is an unusual case, however. Generally the oil must be looked for immediately above the saline crystalline masses or, where these are truncated at the surface, in the highly tilted peripheral layers. Great saline masses may be surrounded by beds wholly lacking in hydrocarbons, as at Petite Anse, Grande Cote, or Jefferson Island. Both actual exploitation and theoretical considerations show clearly that the circle of influence of each saline uplift may be drawn with a radius scarcely ever a mile in length, generally far less.

SYNOPSIS OF SALINE-DOME STATISTICS.

On a glance over the following notes on saline domes, it will be at once apparent how few of these structures have produced oil or gas in commercial quantities. Their present relative importance is indicated by the tables on page 26.

The saline domes of northern Louisiana have yielded so far little oil or gas. But they have been very slightly exploited, especially in the light of present knowledge regarding their structure. The Woodbine sand, being the most extensive producer of oil in the Caddo field and extending doubtless throughout northern Louisiana, may well be looked for on the lateral slopes of the salines at no great depths, for the Annona chalk beds or the "Saratoga" chalk member of the Marlbrook marl outcrop around many of these buried domes. A few known facts about each of these domes are given below:

ANSE LA BUTTE.

Location.—St. Martin Parish, La.; 6 miles from Lafayette, 3 miles from Breaux Bridge, on highway between the two places.

Topography.—A small quadrilateral depression (anse), usually filled with water, flanked by ground or elevations somewhat above the level of the surrounding prairie, especially on the north side, where a "butte" rises 16 feet above the swamp. (See map, Pl. II.)

Indications.—Gas bubbling in margin of swamp and the "butte."

Development.—Taken under consideration as oil territory, 1893; unsuccessfully drilled into under Captain Lucas, 1899; Heywood No. 1 developed small production (40 barrels), fall of 1902; first important well, Lake No. 7, November 14, 1907, a 3,000 to 4,000 barrel gusher. For production, see page 26. A 4-inch pipe line was constructed to Breaux Bridge in March, 1906; the field has use of the Evangeline line to the Atchafalaya, November, 1907. The Lafayette and Baton Rouge branch of the Southern Pacific Railroad skirts the north edge of the field.

Area.—Between 100 and 150 acres.

Geology.—A central salt dome 1,000 feet in diameter at upper truncated portion, covered by infilling of 200 to 300 feet of recent material; laterally salt shelves occur; oil and gas apparently occupying upturned edges of pervious layers pinched out against salt dome by upward movement of the dome. Dips wherever measured are away from center, generally at high angle. Oil and gas in various layers from surface downward, but especially below salt ledge at 1,100 feet (Heywood No. 1) and in "deep sand" at 1,800 feet (Lake No. 7 and others).

References.—Louisiana Geological Survey, Rept. 1899, p. 38, Pl. II; Rept. 1902, p. 266; Rept. 1907, pp. 87–91. Bull. U. S. Geol. Survey No. 212, pp. 63, 130–131; No. 282, pp. 105–110. Oil Inv. Jour., August 15, 1902, p. 7; March 1, 1903, p. 5; February 18, 1906, pp. 12–13; November 19, 1907, pp. 1, 2; many other references to the field are made in this journal.

BARBERS HILL.

Location.—Chambers County, Tex., 20 miles south of Dayton.

Topography.—A plateau-like circular elevation several thousand acres in extent; about 20 feet above surrounding prairie.

Indications.—Escaping gas.

Development.—This low elevation was prospected soon after the Spindletop development; ten wells were put down before March, 1905, some to about 2,000 feet. Patillo Higgins alone sunk five wells here; McCann's 2,000-foot test well abandoned in January, 1905; Guffey test well abandoned at 1,400 feet, October, 1907.

Geology.—Clays, gravel, sand, some limestone layers and gypsum in flakes; nodules or concretions abundant. Guffey 1,400-foot test well abandoned in solid rock salt. Oil and considerable quantities of sulphur reported from about 1,000 feet. Some oil recorded at other depths.

References.—Bull. U. S. Geol. Survey No. 282, p. 83. Oil Inv. Jour., January 18, 1905, p. 3; October 19, 1907, p. 11.

BATSON.

Location.—Western Hardin County, Tex., 7 miles southwest of Saratoga, 13 miles northwest of Sour Lake.

Topography.—In open prairie with saline swamp not far distant; there is no dome here like that at Spindletop.

Indications.—Bubbles of gas rising through pools of water; formerly said to be seepages of oil.

Development.—Paraffine Oil Company brought in first successful well October 31, 1903, from a depth of 790 feet; second well in December had an initial flow of 4,500 barrels daily; production of 1904 nearly 11,000,000 barrels—greater than for all years since.

Area.—Important developments within 250 acres; scattering over 500 acres.

Geology.—As a rule a slightly undulating crystalline porous limestone layer, locally 30 feet thick, lies beneath clay and sand beds at a depth of about 1,100 to 1,200 feet; another layer, 5 or 6 feet thick, is reported at about 600 feet here and there. As at Spindletop, the great gusher production was derived from lower limestone; after salt-water invasion upper sands and thin limestone layer were worked; porous limestone not encountered beyond limits of field.

Oil and gas.—Oil remarkably light for saline-dome oil, 20° to 29.9° B.; yields 6.5 per cent gasoline, 20.4 per cent kerosene, 14.4 per cent solar oil, 46.7 per cent lubricating oil, and 6 per cent asphaltum. Gas encountered in quantity in wells situated along anticlinal axes. For production see page 26.

References.—Bull. U. S. Geol. Survey No. 282, p. 53. Eng. and Min. Jour., vol. 78, p. 139. Oil Inv. Jour., December 1, 1903, p. 2; January 1, 1904, p. 1.

BAYOU BOUILLON.

Location.—At the junction of Bayou Bouillon and Atchafalaya River, 30 miles northeast of New Iberia, La.; exploitation on both sides of the river.

Topography.—Slight mounds on both sides of the river.

Indications.—Gas bubbling in the vicinity, especially along a line crossing the river.

Development.—Maxwell & Sherwood erected a derrick on the west bank and Heywood one on the east bank, summer, 1902; several shallow test wells, and three of 1,000 feet or more, put down before 1905; Robert Martin went back to old Heywood test well, fall, 1907; another old test well deepened, 1908.

Geology.—Logs of wells very different in near-by locations; sand, clay, and gravel predominating; a 300-foot limestone stratum from 850 to 1,150 feet in Maxwell & Sherwood well; hot water reported in a well from 1,200 to 1,280 feet deep; oil and gas showings at various depths.

Oil and gas.—Oil obtained in several bucketfuls in Heywood well; very viscid, dark brown, specific gravity 0.859. Gas 93.72 per cent hydrocarbons; proportion of marsh gas not stated; no hydrogen sulphide.

References.—Oil Inv. Jour., June 21, 1902, p. 3; August 15, 1902; December 5, 1907. Bull. U. S. Geol. Survey No. 282, pp. 112-113.

BAYOU CASTOR.

Location.—Eastern Winn Parish, La., about 5 miles north of Rochelle, near line between secs. 15 and 22, T. 10 N., R. 1 E.

Topography.—Broad, flat, barren stretches like second bottom lands along small bayou branches; pronounced elevation located centrally; marginal slopes steep and wooded.

Remarks.—Vicinity not yet prospected for oil or gas; no indications reported. Presence of salt domes in this vicinity also indicated by salt water in well 400 feet deep at Selma; water yields 3 per cent chloride of sodium.

BIG HILL.

Location.—Western Jefferson County, Tex.

Topography.—Low crescentic rise of several thousand acres in area in coastal prairie.

Indications.—Domelike elevation.

Development.—Two deep wells have been sunk on the hill, also one deep one to the west and one to the east of the hill.

Geology.—Guffey No. 1 well, on east slope of hill, light-gray crystalline dolomite interbedded with gypsum, 350-1,400 feet; below to 2,200 feet gypsum and seams of sulphur; some oil showings. Well a few miles west, at Winnie, finds no rock to bottom, 1,600 feet. Well 1¼ miles northeast abandoned at 1,300 feet. Second deep well on mound goes 2,496 feet to solid limestone, with gypsum and pyrite; rock penetrated 34 feet and well abandoned.

References.—Bull. U. S. Geol. Survey No. 212, p. 126; No. 282, p. 79. Eng. and Min. Jour., July 28, 1904, p. 139. Oil Inv. Jour., June 3, 1905, p. 4; April 13, 1906, p. 27.

BISTINEAU.

Location.—Southern Webster Parish, La., north of Lake Bistineau, south of Vicksburg, Shreveport and Pacific Railway, secs. 25, 26, 35, and 36, T. 18 N., R. 10 W.

Topography.—In Bistineau bottom lands, with brine springs and licks arranged in a circular form, practically duplicating Drake's saline (p. 17).

Remarks.—Not yet tested for oil or gas.

References.—Louisiana Geol. Survey, Rept. 1902, pp. 81–90; Bull. No. 7, p. 56.

BROOK'S SALINE.

Location.—Southwestern Smith County, Tex., 17 miles southwest of Tyler.

Remarks.—Very similar to Steen's, Palestine, and Grand salines, which see.

References.—Texas Geol. Survey, Second Ann. Rept., p. 223. Eng. and Min. Jour., July 28, 1904, p. 137.

BROWN'S SALINE.

Location.—Eastern Winn Parish, La., 18 miles southeast of Winnfield, 6 miles west of Tullos, on north bank of Dugdemone River.

Remarks.—Location as given at Rochelle; place not yet prospected.

BRYAN HEIGHTS.

Location.—Southern Brazoria County, Tex., near mouth of Brazos River, 1 mile from the Gulf and 3 miles from Velasco.

Topography.—A 300-acre moundlike area rising 19 feet above surrounding plain, which is 11 feet above tide.

Indications.—Fragments and small chunks of asphaltic "sea wax" frequently mentioned from this region; the mound is also suggestive of a saline dome.

Development.—Little accomplished of late; seven wells drilled before the fall of 1904; fresh water and an enormous flow (6,000,000 cubic feet daily) of gas, mainly hydrogen sulphide, have been found; some oil found in crystalline limestone, nonproductive; below are sulphur and gypsum.

Geology.—Apparently similar to Spindletop, without the oil; very hard rock layers a few feet thick occur in sand and clay; drill reported as dropping in rock crevice from 598 to 611 feet.

References.—Bull. U. S. Geol. Survey No. 212, p. 127; No. 282, p. 87.

BLUE RIDGE.

Location.—Eastern Fort Bend County, Tex., 15 miles southwest of Houston. Name "Blue Ridge" sometimes used generally for territory from Pierce Junction, 8 miles southwest of Houston, to Missouri City, 17 miles in southwest direction, including Reamers Ridge. Blue Ridge proper is 6 miles south from Pierce Junction.

Development.—A favorite district for "wildcatting," especially between 1904 and 1907. One well drilling in 1904, another in 1905; near-by wells in 1906 and 1907.

Geology.—Well of 1904 reports conglomerate from 200 to 600 feet, with gypsum and dolomitic matrix. Pyrite and sulphur crystals and gas with petroleum odor also reported. Wells from Pierce Junction to Missouri City abandoned at 1,050 to 1,500 feet. Rock salt reported in Beatty well at about 750 feet.

Oil and gas.—Traces of oil found at Blue Ridge and Missouri City; gas in a well at Reamers Ridge and enough gas for a blow-out at Pierce Junction. Oil samples said to be of 17° B. gravity.

References.—Eng. and Min. Jour., July 28, 1904, p. 139. Oil Inv. Jour., June 3, 1905, pp. 4, 18; July 18, 1905, p. 3; May 3, 1905, p. 11; August 18, 1905, p. 3; April 3, 1906, p. 27; January 3, 1907, p. 13; November 5, 1907, p. 12.

COAL BLUFF SALINE.

Location.—Western Sabine Parish, La., about 6 miles northwest of Negreet saline, sec. 33, T. 6 N., R. 13 W.

Remarks.—A small open "lick" showing a few old furnaces. See Negreet (p. 21).

COOCHIE BRAKE.

Location.—Southwestern Winn Parish, La., in sec. 30, T. 10 N., R. 4 W., 5½ miles west of Atlanta station.

Topography.—An uplifted and highly tilted pyritiferous sandstone on the north side of a swamp.

Remarks.—Though various persons have sought for "gold" (pyrite) at this place with some degree of energy, its capabilities as an oil or gas field have not yet been tested. The great uplift here evident, together with the large amount of pyrite in the sandstone, should cause the locality to be carefully studied and properly tested by drilling. Here, as at the marble quarry near Winnfield, there are no brine springs, though doubtless rock salt could be encountered in places by boring a few hundred feet. Similar conditions prevail at Pine Prairie (p. 21).

References.—Louisiana Geol. Survey, Rept. 1899, p. 60; Bull. No. 5, p. 19.

COTE BLANCHE.

Location.—Western St. Mary Parish, La., on Cote Blanche Bay.

Topography.—A nearly circular mound about 2 miles in diameter, rising out of the coastal marsh to a height of 100 feet. (See Pl. XXV, Bull. Louisiana Geol. Survey No. 7.)

Geology.—This, one of the so-called Five Salt Islands, has never been sufficiently exploited to determine its capabilities as an oil or salt producer. Many wells from 300 to 500 feet deep have been sunk in search of salt or water, but so far nothing of importance has been encountered—no hard layers, no salt water, no escaping gas. That this "island" is in reality a saline dome there can be no doubt; to what extent it may become an oil or gas producer is yet undetermined.

References.—Louisiana Geol. Survey, Bull. No. 7, p. 27, Pls. XXVI, XXVII, XXVIII.

COTE CARLINE.

Location.—Iberia Parish, La., 12 miles west of New Iberia; a short distance north of the Bob Acres flag station on the Abbeville branch of the Southern Pacific Railroad.

Topography.—A rudely elliptical mound about three-fourths of a mile in major diameter, rising out of the level coastal plain on the south side of Lake Peigneur to a height of about 70 feet.

Development.—Salt was discovered on this "island" in 1895 in a well at 334 feet, being sunk for fresh water, mineral water, or whatever might be of value; eight test wells were sunk to ascertain the contour of the salt mass.

Geology.—Salt approaches in places within 91 feet of the surface. It was on this island that the great depth of these coastal salt masses was first determined. Diamond-drill cores to a depth of 2,090 feet showed only solid rock salt. So far no oil or gas indications of importance have been reported on this dome.

References.—Eng. and Min. Jour., vol. 62, pp. 463–464. Louisiana Geol. Survey, Rept. 1899, p. 254; Rept. 1907, p. 86, Pl. XXIX.

DAMON.

Location.—Northwestern Brazoria County, Tex.

Topography.—A rudely circular mound rising in its most elevated portion 75 feet above the surrounding prairie; diameter nearly 2 miles.

Indications.—Sour dirt or "vitæ ore" formerly shipped from this mound in carload lots for medicinal purposes; presumably resulting from decomposition brought about by escaping sulphurous gases.

Development.—At least five wells drilled, showing remarkably varying records.

Geology.—Shows typical dome material, especially in central portions. The Herndon well gave the following:

	Feet.
Gypsum	171- 549
Sulphur and gypsum	549- 579
Loose sand, very coarse	579- 587
Salt	587-1,160

References.—Bull. U. S. Geol. Survey No. 212, p. 36; No. 282, p. 90. Eng. and Min. Jour., July 28, 1904, p. 138.

DAVIS HILL.

Location.—Northern Trinity County, Tex., on right bank of Trinity River.

Topography.—Various hills or rises reported as 250 feet above the surrounding prairie.

Indications.—Escape of sulphurous water and inflammable gas.

Development.—Four wells drilled in 1905 and 1906.

Geology.—One well reported as "twisted off" at 1,000 feet, with good oil showing at that depth. Rock at 1,000 feet in the Cherry well was supposed for a time to be oil bearing; came in a gusher of hot black sulphur water, February 9. Others at 1,100 feet show water at various horizons but no oil.

References.—Oil Inv. Jour., January 18, 1906, p. 6; March 18, 1906, p. 8. Bull. U. S. Geol. Survey No. 212, p. 127.

DAYTON.

Location.—Scene of interest is about 8 miles west-northwest of Dayton, southwest-central Liberty County, Tex.

Topography.—Poorly defined elevated region, 6 miles wide and 10 miles long, rising 20 to 30 feet above surrounding prairie.

Indications.—Abundant gas escapes in springs, ponds, post holes, shallow wells, etc.

Development.—Several years before oil was found at this locality in 1904 T. R. McGowan used his shallow gas wells for domestic purposes. The Willard-Bullard well reached a shallow sand at about 400 feet, producing perhaps 25 barrels daily. A Higgins-Paraffin was the first successful well, April, 1905, rated as 100 barrels; first gusher, Higgins-Paraffin No. 4, from 740-foot sand, August 28, 1905; for production later, see page 26.

Geology.—Sections of wells various; typical saline-dome material found in some wells; coastal clays and sands to 580 feet, limestone to 590, gypsum to 799, rock salt to 1,299 feet; elsewhere rock salt is sometimes mixed with sand. Higgins No. 2 obtains oil from rock; No. 4 from sand 20 to 30 feet thick.

Oil and gas.—Oil from Higgins-Paraffin No. 1, 17.1° B., from No. 4, 24° B. Gas encountered from surface to bottom of wells, especially in northwestern part of field; blow-outs often referred to.

References.—Bull. U. S. Geol. Survey No. 212, p. 126; No. 282, p. 85. Oil Inv. Jour., April 15, 1904, p. 1; September 3, 1905, p. 1.

GOLDONNA (DRAKE'S SALINE).

Location.—West margin of Winn Parish, La., about the center of T. 12 N., R. 5 W.

Topography.—Several flat barren "licks" surrounded by low steep banks; many of them moundlike. (See p. 49.)

Development.—Besides the old artesian well and various shallow wells, all of very uncertain depths, two important wells are known at this locality. The most interesting is that of Savage Brothers and Morrical, sunk in 1905–6 to a depth of 2,342 feet, showing 1,410 feet of rock salt. A second well, half a mile north of first, showed no salt but some oil and gas; other details lacking.

Geology.—Appears to be a salt-dome uplift, truncation of dome resulting from enormous thickness of overlying concretionary cavernous limestone. (See p. 50 for an ideal section through this locality.)

References.—Louisiana Geol. Survey, Rept. 1902, pp. 51–64; Bull. No. 7, p. 501.

GOOSE CREEK.

Location.—Southeast corner of Harris County, Tex., across San Jacinto Neck from La Porte.

Topography.—Seemingly a low mound eroded on the one side by San Jacinto Bay, on the other by Goose Creek.

Development.—Houston people prospecting at this locality in summer of 1907 found enough oil in first well between 1,000 and 1,100 feet to supply fuel for second well. Considerable gas and a blow-out are recorded at 1,500 feet. Goose Creek No. 4 first gusher. Wells have been carried to depths of 1,925 and 2,500 feet, but the total production is small, about 11,000 barrels for last half of 1908.

Geology.—Stated by Hager to be a real dome in structure, with the usual dome materials, in spite of the fact that the oil "sand" is unusually deep (about 1,600 feet) for Gulf border production.

Oils.—Cedar color, heavy gravity, 17.5° B. in 1,600-foot wells, 23° B. in 1,700-foot well.

References.—Oil Inv. Jour., November 19, 1907, p. 9; February 5, 1908, p. 5; March 5, 1908, p. 12; May 5, 1908, p. 7; June 19, 1908, p. 3, and especially July 6, 1908, p. 21.

GRAHAM'S AND STIVER'S SALINES.

Remarks.—Given on Hager's map (Eng. and Min. Jour., July 24, 1904, p. 137) as in southern Angelina County, Tex. The writer has no personal knowledge of these salines.

GRANDE COTE (WEEKS ISLAND).

Location.—Southwestern Iberia Parish, La., on east side of Weeks Bay, an eastern lobe of Vermilion Bay, 15 miles south of New Iberia.

Topography.—Nearly circular dome 125 feet in height, 2 miles in diameter, and, like all other domes, more or less dissected.

Development.—Exploited particularly for salt since 1897. About fifty shallow holes have been sunk to determine contour of salt. Myles Salt Company has opened a large salt mine on this island.

Geology.—This, like Petite Anse (Averys Island), is known only as a salt island, no important indications of oil or gas having ever been noted.

References.—Louisiana Geol. Survey Bull. No. 7, pp. 5–14, Pls. XIII, XVII.

GRAND SALINE.

Location.—Van Zant County, Tex., on Texas and Pacific Railroad.

Remarks.—This large saline, 1 mile long by half a mile wide, is regarded by Veatch as due to salt in regular bedding, that is, not redeposited in dome structure (Prof. Paper U. S. Geol. Survey, No. 46, 1906). That rock salt occurs here in thick masses is proved by borings. A showing of oil in a water well of the Southern Salt Company has been reported (Oil Inv. Jour., February 3, 1907, p. 13). (See First Ann. Rept. Texas Geol. Survey, p. 35.)

HACKBERRY ISLAND.

Location.—Cameron Parish, La., 33 miles southwest of Lake Charles, between Black Lake and Calcasieu Lake.

Topography.—Low elevation of 35 feet in an area of about 8,000 acres.

Indications.—Escape of gas and sulphureted waters.

Development.—Three wells; Louisiana-Texas Oil Co. No. 2 on Northwest side of island, depth 1,830 feet; Nos. 1 and 3 on east side, 1,460 feet.

Geology.—No. 2, thin layers of rock only to a depth of 1,565 feet, then a 45-foot bed of cavernous limestone; below, 10 feet of pure black sand and 210 feet of "gypsum." Nos. 1 and 2 with "rock" in thin layers at intervals below depth of 900 feet. A 7-foot lignite bed recorded at 1,421 feet in No. 1; an oil showing at 1,460 feet. Salt water and an oil showing supposed to have come from black sand bed of No. 2.

References.—Bull. U. S. Geol. Survey No. 212, p. 131; No. 282, p. 111.

HIGH ISLAND.

Location.—Southeastern Chambers County, Tex., 1 mile from the coast and halfway between Sabine Pass and Galveston.

Topography.—More or less circular elevation 48 feet above Gulf level and about 1¼ miles in diameter; considerably dissected.

Indications.—Inflammable and sulphurous gases and moundlike appearance.

Development.—Many shallow test wells for fresh water were put down early, because waters are all either saline or sulphurous. Showings of oil noted at 505, 972, and 1,200 feet. Several deep wells record very thick deposits of gypsum. Some small quantities of oil obtained at 1,200 feet, but salt water soon drowned it out.

Geology.—A typical saline dome; a Guffey well passed through gypsum from 600 to 1,200 feet. Another encountered gypsum from 900 to 1,300 feet, then rock salt to 2,600 feet, bottom of well. Sulphur, galena, sphalerite, barite, etc., are common.

References.—Bull. U. S. Geol. Survey No. 212, p. 123; No. 282, p. 81. Oil Inv. Jour., February 5, 1908, p. 18.

HOCKLEY.

Location.—Northwestern Harris County, Tex., 4 miles south of Hockley station, on Houston and Texas Central Railroad.

Development.—Five test wells reaching depths from 500 to 850 feet were put down at this locality in 1906 by Patillo Higgins. His No. 1 is reported as passing through rock from 14 to 524 feet; rock appears to be white limestone. Last test well in salt at shallow depth; operations abandoned.

References.—Oil Inv. Jour., June 5, 1906, p. 17; August 18, 1906, p. 2; September 3, 1906, p. 10; July 19, 1907, p. 6; July 20, 1908, p. 20.

HOSKINS.

Location.—Eastern Brazoria County, Tex., between Chocolate and Eastrop bayous.

Topography.—A mound 700 acres in area elevated 30 feet above the surrounding plain.

Development.—Drilling followed by a blow-out recorded in 1904. Up to summer of 1907 the Mound Company had drilled thirteen wells; the No. 2 was the first successful one, drilled in November, 1905, but kept secret till May, 1906. Production for all wells, 1908, 15,875 barrels.

Geology.—Well No. 2 produced 60 to 125 barrels daily for over a year, from a depth of 582 feet. Rock layers occur at 600 to 800 feet and below, some described as sand cemented by carbonate of lime. Rock salt in well No. 9 at 1,350 feet. Rock salt in one well from 1,250 to 1,700 feet.

Oil.—Greenish, low in sulphur, 21.5° B. Good gas wells are secured.

References.—Bull. U. S. Geol. Survey No. 282, pp. 86, 138. Oil Inv. Jour., May 3, 1906, p. 1; June 3, 1906, p. 14; June 5, 1907, p. 19; August 5, 1907, p. 18; December 19, 1907, p. 9.

HUMBLE.

Location.—Harris County, Tex., 18 miles north of Houston, 1½ miles east of Humble station, on Houston East and West Texas Railway.

Topography.—Part of Echols Ridge, 100 feet above sea level. This is the largest saline-dome oil field of this region and extends in a northeast-southwest direction for 2 miles.

Indications.—Gas escapes.

Development.—Begun by a shallow well terminating in a blow-out, 1902; some oil and gas found between 1,000 and 1,250 feet, December, 1904; the gusher, Beatty No. 2, completed January 7, 1905, producing over 8,000 barrels daily for several days; by March 1 the field was producing 90,000 barrels daily and shortly salt water appeared. For remarkable production of 1905 and decrease since, see page 26.

Geology.—Beatty No. 2 encountered its 80-foot cap rock at a little more than 1,200 feet. Thin rock layers at several places are mentioned in the logs.

Gas and oil.—Field is remarkable for its gas pressure at 800-foot level; gas below with oil is poisonous; oil of heavy coastal saline-dome type mainly; also a light-green oil of 20° B. gravity; a few showings of 29° B. oil occur.

References.—Oil Inv. Jour., November 5, 1904, p. 1; December 1, 1904, p. 1; January 1, 1905, p. 10; February 3, 1905, p. 5; June 3, 1906, p. 1; June 3, 1906, pp. 1–4.

JENNINGS.

Location.—Western Acadia Parish, La., 6 miles northeast of Jennings station, on the Southern Pacific Railroad.

Topography.—Broad erosional depression 10 feet above sea level west of a low hill or mound rising 32 feet above sea level.

Indications.—Gas escape in a spring in a comparatively elevated position.

Development.—First regarded as a favorable locality for oil after the famous Lucas well at Spindletop was brought in, January 10, 1901. A local concern, the Jennings Oil Company, hired the Heywood Brothers to sink the first well; well stopped in "pay sand" at 1,822 feet in August, 1901; flowed spasmodically, proving the existence of oil in considerable quantities. First really great wells obtained as the operations advanced to the south and east in 1904. For production, see page 26. Over 450 wells have been sunk in this field. Increase of production was accompanied by the building of wooden, steel, and earthen storage tanks, especially the last, of enormous dimensions. The field was also connected by pipe line with the Southern Pacific Railroad at Jennings, Mermentau, and Egan; the Kansas City Southern Railway at Lake Charles; and Atchafalaya River.

Area.—About 1 square mile, unusually great for a saline-dome oil field.

Geology.—East-northeastern third of the field with *Rangia johnsoni* Miocene fauna within 1,000 feet of the surface—that is, below but 1,000 feet of Quaternary beds; in the west-northwestern half, Quaternary deposits extend to 2,200 feet or even deeper. Great gusher production along or near the north-northeast and south-southwest fault line; material in general exceptionally coarse along this line, and lenses of rock very numerous near the north end of the line in the productive field; oil evidently ascends through fault fissure and spreads out into various pervious sands, in places nearly reaching the surface.

Oil and gas.—Oil heavy, with less sulphur than in Spindletop oil. Gas pressure less than at Spindletop.

References.—Bull. U. S. Geol. Survey No. 212, p. 127; No. 282, p. 94. Louisiana Geol. Survey, Rept. 1902, p. 268; Bull. No. 7, p. 33. Oil Inv. Jour., all numbers from 1901 to 1909, inclusive.

KING'S SALINE.

Location.—Southern Bienville Parish, La., secs. 34 and 35, T. 15 N., R. 8 W.

Topography.—Low bottom lands along Bayou Castor; Cretaceous outcrop with fossils present.

Remarks.—Vicinity not yet tested for oil and gas.

References.—Louisiana Geol. Survey, Rept. 1902, p. 76; Bull. No. 7, p. 56.

KISERS MOUND.

Location.—Western Brazoria County, Tex., 3 miles northwest of Columbia, just west of Brazos River.

Topography.—A mound rising 30 feet above the surrounding plains, more or less irregular in outline.

Development.—Six or eight wells drilled on mound or vicinity, dating from 1901; one well reported to have reached depth of 1,050 feet; a flow of 5 barrels daily of lubricating oil was obtained from one well for sixteen months from a depth of 480 feet; other small showings are noted; some gas and occasional blow-outs are recorded.

Geology.—Rock may be encountered at depth of 60 to 400 feet; irregularly below; porous limestone, sulphur, sandstone with streaks of salt, dolomite in regular masses, pyrite, artesian water, all noted in this true saline dome.

References.—Bull. U. S. Geol. Survey No. 212, p. 125; No. 282, p. 88. Eng. and Min. Jour., July 28, 1904, p. 138. Oil Inv. Jour., February 18, 1907, p. 5; March 5, 1907, p. 17; May 19, 1907, p. 3.

MANY.

Location.—Northeastern Sabine Parish, La., near Rock Spring Church, NE. ¼ sec. 24, T. 8 N., R. 11 W.

Remarks.—Dome structure is inferred here on account of the occurrence of fossils of decided Midway Eocene aspect in region of Wilcox ("Sabine") Eocene. See Louisiana Geol. Survey, Rept. 1899, p. 63.

MARKHAM.

Location.—Matagorda County, Tex., 6 miles northwest of Markham station, 12 miles from Bay City.

Topography.—Low domelike elevation but little elevated above the level of the surrounding plain; axis northeast-southwest.

Development.—Field opened up by Hardy well No. 1, June, 1908; seventeen wells drilled in 1908, five producing, twelve dry, thirteen abandoned.

Geology.—Oil first found in sandy strata in shale, between 1,306 and 1,370 feet; amount of clay remarkable; thickness of oil sand not determined; Hardy No. 1 apparently on south flank of buried northeast-southwest fold (Hager); productive area limited to a few hundred feet. Some wells attain a depth of 1,900 feet.

References.—Oil Inv. Jour., June 19, 1908, p. 1; July 6, 1908, p. 20; February 6, 1909, p. 22.

MATAGORDA.

Location.—Big Hill, Matagorda County, Tex., near mouth of Colorado River, 5 miles northeast of the village of Matagorda.

Topography.—Dome of about 100 acres, rather flat-topped, rising 36 feet above Gulf level, or 20 to 24 feet above the coastal plain.

Development.—Activities in this field increased through 1903 and 1904, culminating in December, 1904, when the field went largely to salt water. Thirty wells had been drilled, about one-half of which were producing. The 4-inch pipe line to the Santa Fe Railway was taken up in 1907. Production: 1904, 80,591 barrels; 1905, 46,471 barrels; 1906, 8,000 barrels; 1907, 4,500 barrels; 1908, 2,000 barrels.

Geology.—A typical coastal saline dome; sections show sand and clay mostly to 800–1,000 feet, according to location on dome; then a cavernous limestone, "cap rock;" sulphur crystals common; best gas and oil obtained near apex of dome; one gas well estimated to flow 5,000,000 cubic feet a day, mostly H_2S mixed with SO_2; hot sulphurous water (99.6° F.) sometimes encountered.

References.—Oil Inv. Jour., April 15, 1904, p. 1; January 19, 1908, p. 12. Bull. U. S. Geol. Survey No. 282, p. 63. Eng. and Min. Jour., July 28, 1904, p. 138.

NEGREET.

Location.—Western Sabine Parish, La., about half a mile above mouth of Negreet Bayou, in the SW. ¼ sec. 24, T. 5 N., R. 13 W.

Topography.—Level, barren stretches on banks of bayou, without vegetation; vegetation killed by brine seepages; strongest brine, however, in bayou.

Remarks.—It is quite probable that the secondary structural features brought about by this and the Coal Bluff saline are responsible for the local concentration of oil and gas mentioned under "Negreet," page 32.

PALESTINE.

Location.—Anderson County, Tex., 6 miles southwest of Palestine.

Topography.—Lowland surrounded by hills 60 feet high, showing Cretaceous beds with fossils; highest surrounding rocks, red sandstone.

Remarks.—Rock salt here has been penetrated to a depth of more than 100 feet; thickness unknown; oil and gas possibilities undetermined.

References.—Texas Geol. Survey, First Ann. Rept., p. 35. Eng. and Min. Jour., July 28, 1904, p. 137.

PETITE ANSE.

Remarks.—Petite Anse, or Avery's Island, as it is frequently called, is a well-known and important salt "island," but so far the writer has learned of no occurrences of oil indications upon or about it. It is situated in western Iberia Parish, La., on a branch of the Southern Pacific Railroad. For description of test wells, salt shaft, etc., see Louisiana Geol. Survey, Bull. No. 7, pp. 14 et seq.

PINE PRAIRIE.

Location.—Northwestern St. Landry Parish, La., on Bayou Chicot; often referred to as Bayou Chicot or St. Landry "marble" quarry.

Topography.—An irregularly eroded district in the border of the hill lands just north of the coastal prairies of southern Louisiana. A few limestone ledges are seen cropping out on a northward-facing hillside.

Indications.—Black, fine asphaltum particles filling limestone pores, in limestones at surface outcrops.

Development.—Limestone worked and burned before the civil war; scores of shallow hand-drill holes about the limestone outcrops to determine extent of limestone. Myles Mineral Company began drilling for oil in June, 1909; several shallow wells sunk through surface rock; wells more than 500 feet deep reach rock salt; a third deep test well is being sunk.

Geology.—The light concretionary limestone of the type seen at Winnfield and encountered in so many coastal wells here comes to the surface; center of uplift is a salt dome; some small quantities of a heavy oil have already been obtained.

References.—Louisiana Geol. Survey, Bull. No. 7, p. 35.

PRICE'S SALINE.

Location.—Northern Winn Parish, La., on Dugdemona Creek, in sec. 30, T. 13 N., R. 4 W., and sec. 25, T. 13 N., R. 5 W.

Topography.—More or less domelike hill half a mile in diameter, 90 feet high, surrounded by low salt licks.

Remarks.—So far as known, no tests for oil or gas have been made in the vicinity of this saline.

References.—Louisiana Geol. Survey, Rept. 1902, pp. 64–70; Bull. No. 7, p. 54.

RAMBO SALINE.

Location.—Northeastern Marion County, Tex., 2½ miles west of Texas-Louisiana state line, very nearly due west of Vivian, La.

Remarks.—This is not an extensive saline, nor do the bordering higher lands rise so abruptly from the flats as is generally the case. However, the smooth, flat barren areas bordered by stunted growths of spinose shrubbery would clearly indicate the true nature of this desolate spot, even though the ruins of former salt works were removed. This saline seems to be some distance north of the northern limit of the Sabine uplift, evidently bearing the same relation to the northward slope of this great subterranean plateau that Bistineau, King's, Drake's, etc., do to the eastern slope. This saline is not known to be mentioned in literature, and hence no references can be given. The writer visited the region in December, 1908.

RAYBURN'S SALINE.

Location.—Southeastern Bienville Parish, La., in sec. 13, T. 15 N., R. 5 W., about 8 miles southeast of Bienville.

Topography.—Low swampy bottoms with extensive "licks." Slight rise to the east with Cretaceous fossils.

Remarks.—There is no record that any test wells have been put down for oil or gas in this vicinity, though the Cretaceous outcrop in a Claiborne Eocene region speaks clearly of the enormous uplifting that has taken place here.

References.—Louisiana Geol. Survey, Rept. 1902, pp. 71-75; Bull. No. 7, p. 54.

SARATOGA.

Location.—West-central Hardin County, Tex.

Topography.—Relief within a radius of a mile perhaps 15 or 20 feet; dissected by tributaries of Pine Island Bayou; no hill nor dome noticeable.

Indications.—Gas escapes and oil seepages; also sulphureted and sour waters.

Development.—Earliest drilling, done by spring pole, obtained a few gallons of heavy oil for medicinal purposes; Savage Brothers drilled a 250-foot well in 1896, yielding an artesian flow of oil and water. Serious attempts toward developing the field commenced after the 1901 success of Beaumont; Hook's No. 1 in 1902 flowed from about 1,000 feet, the Brice well from 400 feet; it became generally understood in 1903 and 1904 that the best horizons were between 800 and 1,000 feet and a large number of wells were sunk to these depths; a second and deeper sand was developed in southwestern part of field early in 1905, producing large amounts of oil for a few weeks, going to salt water. For production, see page 26.

Geology.—Certain rocky layers have been mentioned as reaching the surface in and by a small lake, corresponding evidently to the "lake" at Sour Lake. Fenneman gives few references to consolidated matter in a large number of wells drilled to 1905; sand and clay predominate, with an unusually large percentage of the former; geology of field clearly of Jennings type, though fossils of no greater age than Quaternary were said to have come from just above the shallow oil (800 feet). Salt-dome action is shown in tilting of rocks in the lake.

References.—Oil Inv. Jour., June 1, 1903, p. 3; August 15, 1903, p. 10; January 1, 1905, p. 2; February 3, 1905, p. 1. Bull. U. S. Geol. Survey No. 282, p. 57.

Oil and gas.—Shallow oil, 16° to 18° B.; deeper, 22° B. Suitable for fuel, mostly used for that purpose. Gas found especially above oil, in pockets, under great pressure.

SOUR LAKE.

Location.—Southern Hardin County, Tex., 20 miles in a direct line west-northwest of Beaumont.

Topography.—Dome structure not appreciable at surface; sunken area of Sour Lake somewhat noteworthy; relief scarcely 10 feet.

Indications.—Gas and oil escapes, asphaltum-like masses at the surface, "sour" waters.

Development.—Locality known as a health resort as early as the fifties, the sour-water springs being the attraction; Savage Brothers drilled shallow wells and got some heavy lubricating oil in 1895; a small refinery was opened in 1898, for manufacture of lubricating oil. Serious development began early in 1901; Guffey Company struck gas pocket at 822 feet and found good oil sand at 1,400 feet in summer of 1901; simultaneously, Atlantic and Pacific Company developed oil horizon at 700 feet; new wells, railway connection with Southern Pacific Railroad, pipe lines, steel and earthen tankage soon in operation; over 8,000,000 barrels produced in 1903; present production about 1,500,000 barrels annually.

Geology.—Logs of wells to 1,600 feet or more show usually clays and sands, with thin "rock" layers; oil from various sands. A small east-west area 250 by 700 feet in Wirt, Davis & Gilbert tract underlain by porous oil-bearing crystalline limestone, 20 to 100 feet thick, dipping northeast, at depths of 660 to 880 feet. Rock salt encountered not far beneath porous limestone. Jackson Eocene fossils obtained from Atlantic and Pacific to Cannon tracts, at depths ranging from 1,500 to 1,000 feet or less; Oligocene species from Sour Lake Hotel to Shoestring tract at 800 to 600 feet and probably less.

Oil and gas.—Oil like that at Spindletop, averaging 22° B.; shallow oil, 16° to 18° B.; deep oil (1,300–1,400 feet), 24.7° B. Gas abundant, that from cavernous limestone with oil, poisonous; utilized by gas engines.

References.—Bull. U. S. Geol. Survey No. 212, p. 113; No. 282, p. 88. Louisiana Geol. Survey, Rept. 1902, p. 273. Oil Inv. Jour., August 15, 1903. p. 10; November 1, 1904, p. 3. Eng. and Min. Jour., July 28, 1904, p. 139. Jour. Franklin Inst., vol. 154, p. 234.

SPINDLETOP.

Location.—Northern Jefferson County, Tex., 3 miles south of Beaumont.

Topography.—More or less circular mound about 225 acres in extent, rising in places 15 feet above the level of the prairie.

Indications.—Gas escapes in pools of shallow water; incrustations of sulphur in soil, this being doubtless the controlling indication leading to the sinking of the Lucas well (for sulphur).

Development.—Higgins attempts abandoned (1892) at 300 feet for lack of proper drilling devices; other attempts—Sharp & Co. (1894), J. Loomey (1896), Savage Brothers (1898)—unsuccessful; Lucas interests Guffey Company in probable value of field for sulphur, drilling began on discovery well in October, 1900. Famous Lucas gusher brought in January, 1901, obtaining oil from 1,120 to 1,139 feet; estimated flow, 75,000 barrels daily; fifteen wells completed by July 1, 1901; marvelous development and rapid decline of field shown by statistics of production on page 26.

Geology.—Deeply buried salt dome (1,650 to 1,950 feet), covered by perhaps 600 feet of gypsum, 20 feet of oil-bearing porous crystalline limestone, and 1,000 feet or more of clay, sand, gravel, and hard-rock lenses or layers. Dome flattened centrally, dipping strongly along margins. Oil limestone seemingly not extending beyond pronounced dome structure. Famous gusher product from limestone; later developments in more shallow sands; pyrite and sulphur abundant. All fossils seen latest Tertiary or Quaternary, probably the latter.

Oil and gas.—Gravity 22°-24° B. Average refined products, gasoline 1.8 per cent, kerosene 17.1 per cent, solar oil 15.4 per cent, lubricating oil 52.2 per cent, asphalt, 7.5 per cent. Gas just above oil rock, in enormous quantities, harmless; that in oil rock under great pressure, poisonous.

References.—Trans. Am. Inst. Min. Eng., Richmond meeting, February, 1901; idem, 1902, p. 31. Univ. Texas Min. Survey, Bull. No. 1, p. 8. Louisiana Geol. Survey, Rept. 1902, p. 273; Rept. 1907, p. 100. Bull. U. S. Geol. Survey No. 212, pp. 69-85; No. 282, pp. 18-38. Oil Inv. Jour., all numbers.

STEEN'S SALINE.

Location.—Smith County, Tex., 14 miles north of Tyler, 5 miles east of Lindale.

Topography.—A long, narrow prairie (1 to 2 miles in length) surrounded by hills 30 to 60 feet high showing limestone outcrops.

Remarks.—The writer is not aware that the oil and gas possibilities of this saline dome have been investigated.

References.—Texas Geol. Survey, Second Ann. Rept., p. 223. Eng. and Min. Jour., July 28, 1904, p. 137.

SULPHUR.

Location.—West-central Calcasieu Parish, La., 3 miles northwest of Sulphur station, on the Southern Pacific Railroad.

Topography.—Relief but slight, swampy depression present.

Indications.—Oozing of petroleum, escape of gas, presence of sulphur springs.

Development.—Louisiana Oil Company formed about 1868 to bore for oil; slight quantities obtained at 380 feet; immense sulphur deposits encountered at 443 feet. Importance of sulphur deposits overshadows all else; oil not developed.

Geology.—Apparently a saline dome with an unusually large amount of crystalline sulphur in the porous limestone and gypsum beds.

References.—Louisiana Geol. Survey, Rept. 1899, pp. 25, 126; Rept. 1902, p. 272. Bull. U. S. Geol. Survey No. 212, p. 133.

VINTON.

Remarks.—This low, broad, rock-core dome, located in the coastal prairie about 3 miles southwest of Vinton station, on the Southern Pacific Railroad in western Calcasieu Parish, La., though interesting geologically, has thus far furnished but very small amounts of oil, and these from very shallow depths. See detailed report, page 103.

WELSH.

Location.—Eastern Calcasieu Parish, La., about 3 miles northwest of Welsh station, on Southern Pacific Railroad.

Topography.—A slight swell in the open prairie, due largely to differential erosion.

Indications.—Gas bubbling up in Mr. Wood's irrigation well.

Development.—A well in 1902 encountered some oil at a little more than 1,000 feet; about 25 wells on the slight mound have proved small producers; considerable prospecting in surrounding territory has been without results.

Geology.—Very little consolidated material here encountered; structure unknown, except that certain oil sands in southeastern part of field seem to dip southward; oil in sand about 1,000 feet deep generally.

Oil and gas.—Oil of common heavy saline-dome type, but usually regarded as exceptionally good for lubrication. Gas found over greater area than oil; several remarkable blow-outs recorded.

References.—Bull. U. S. Geol. Survey No. 212, p. 136; No. 282, p. 102. Oil Inv. Jour., December 19, 1907, p. 8.

WINNFIELD (CEDAR CREEK SALINE).

Location.—Winn Parish, La., 3 miles southeast of Winnfield, in secs. 30 and 31, T. 11 N., R. 2 W.

Topography.—Several barren "licks" near Cedar Bayou nearly surrounded by rather abruptly rising irregular, moundlike elevations 5 to 15 feet in height.

Indications.—Gas bubbling up in considerable quantities through springs and shallow water pools.

Development.—Besides several shallow wells, two important test wells have been sunk. The first, in 1904, depth 750 feet, by Winnfield Oil Company, experienced blow-out, lifting 4 inches from hole. Now yields much gas and salt water. The second, in 1907, by Pace Oil Company, encountered rock at 78 feet; after seven months of hard work in rock attained a depth of 1,000 feet; reported as stopped in igneous rock, but will deepen.

References.—Louisiana Geol. Survey, Bull. No. 5, p. 10. Oil Inv. Jour., July 1, 1904, p. 10; April 5, 1907, p. 24.

WINNFIELD (MARBLE QUARRY).

Location.—Winn Parish, La., secs. 19 and 24, T. 11 N., R. 3 W.

Topography.—Rugged, with relief of 70 feet, cavernous crystalline limestone cropping out extensively.

Remarks.—Once extensively worked as a limestone quarry; various reports, not confirmed, that attempts are in progress to test by drilling. This is by far the greatest surface outcrop of the light-blue and white crystalline cavernous limestone so frequently mentioned as a cap rock or oil reservoir in the salt domes of Louisiana and Texas.

References.—Louisiana Geol. Survey, Rept. 1899, p. 56; Bull. No. 5, p. 14, pl. I.

PRODUCTION.

Saline-dome production to January 1, 1909.[a]

[In barrels of 42 gallons each.]

Year.	Louisiana.			Texas.	
	Jennings.	Welsh.	Anse la Butte.	Spindletop.	Sour Lake.
1901	....	....	....	3,593,113	....
1902	548,617	....	....	17,420,949	[b] 44,838
1903	892,609	25,162	....	8,600,905	[b] 8,848,159
1904	6,683,066	35,892	....	3,433,842	6,442,357
1905	8,891,416	10,000	9,000	1,652,780	3,362,153
1906	9,025,174	23,936	23,708	1,077,942	2,156,010
1907	4,895,905	47,316	76,938	1,699,943	2,353,940
1908	4,856,889	43,976	219,265	1,741,070	1,580,655
	35,793,676	186,342	328,911	39,220,544	24,788,112

Year.	Texas.				
	Saratoga.	Batson.	Dayton.	Humble.	Other fields.
1903	150,000	4,518	....	....	....
1904	739,239	10,904,737	....	....	151,936
1905	3,125,028	3,774,841	60,294	15,594,310	46,471
1906	2,182,057	2,289,507	92,850	3,571,445	80,591
1907	2,130,928	2,164,453	108,038	2,929,640	29,286
1908	1,700,986	1,584,500	39,901	3,777,316	94,904
	9,878,238	20,722,556	301,083	25,872,711	[c] 403,188

[a] From Oil Investors' Journal, February, 1909.

[b] Includes production of Saratoga.

[c] Includes 151,936 barrels produced at Matagorda in 1904; 46,471 barrels produced at Matagorda in 1905; 80,591 barrels produced at Matagorda and Hoskins Mound in 1906; 13,267 barrels produced at Matagorda and Hoskins Mound and 16,019 barrels produced at Piedras Pintas and San Antonio (Mission field) in 1907; 15,875 barrels produced at Hoskins Mound, 11,160 barrels produced at Goose Creek, 5,000 barrels produced at San Antonio, and 2,000 barrels produced at Matagorda in 1908.

STRATUM OIL AND GAS.

OCCURRENCE.

The general mode of occurrence of oil and gas at clearly defined geologic horizons, extending in a somewhat continuous manner over vast areas, is well understood. Given water, oil, and gas in a pervious layer sealed above and below by impervious layers, difference in gravity will cause these three substances to be so separated that the water will be below, oil in the middle, and gas on top. Anticlines and quaquaversals of the usual types will naturally cause local concentrations, if the pervious layer is homogeneous throughout.

The large amounts of gas and oil found in the Caddo field, Louisiana, appear to be simply following east and north slopes of a great uplift, and concentrating or reconcentrating along slight anticlinal ridges. Figure 1, taken in connection with the section shown in figure 2, shows these simple stratigraphic conditions very clearly. The writer is not personally familiar with the Corsicana field, but from written descriptions would judge that the trapping of the oil and gas of that field is brought about by the change in character of the eastward-dipping Cretaceous beds, whereby oil and gas, though urged upward and westward for some distance in coarse-grained layers, are finally stopped by the fineness and compactness of the material they encounter. Hopes may be entertained of finding oil and gas so entrapped in wells sunk in various places near the Eocene-Cretaceous contact from Arkadelphia to and beyond San Antonio.

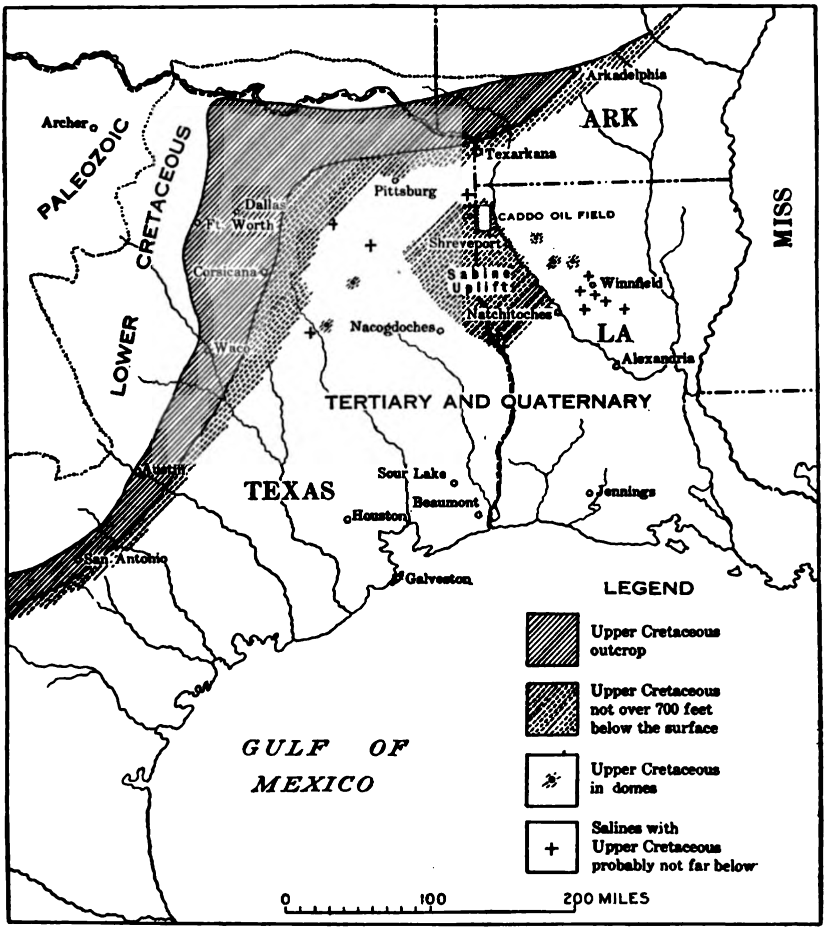


FIGURE 1.—Map showing the important structural features in the Upper Cretaceous (gas and oil bearing) formations in eastern Texas and Louisiana. These formations dip beneath younger (Tertiary and Quaternary) deposits to the southeast. The extensive crustal movements in the vicinity of the Sabine uplift have brought Upper Cretaceous beds up within less than 700 feet of the surface over a large area. This movement has brought about structural features of prime importance in oil and gas concentration.

The middle Eocene deposits of Sabine Parish, La., and Nacogdoches and Anderson counties, as well as to the south of Austin and San Antonio and near Laredo, Tex., are supposed to contain oil,

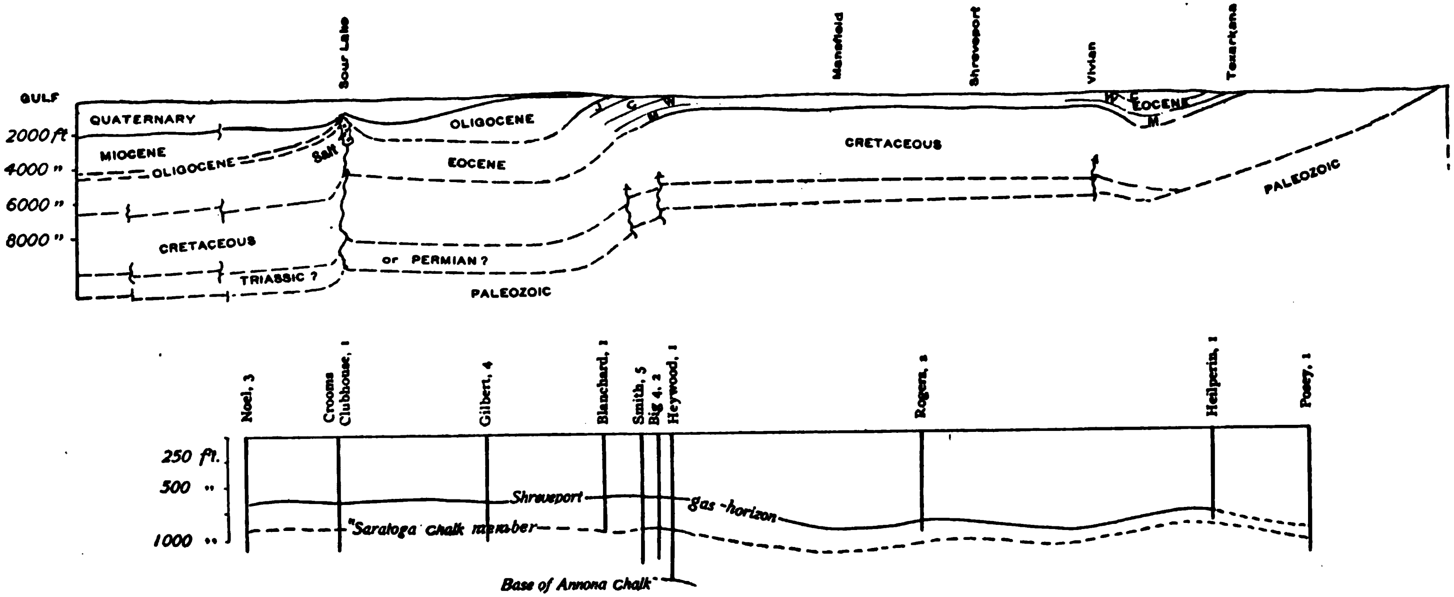


FIGURE 2.—North-south sections through the Sabine uplift. Upper section extending from the Paleozoic outcrop in Arkansas, north of Texarkana, through the Caddo field, and Sour Lake to the Gulf near Galveston. Lower section showing slight folds in Upper Cretaceous beds in the Caddo field, from Posey No. 1 well near Vivian to Noel No. 3 well near Mooringsport.

locally at least, of the wide-extended or stratum type. The geology of these deposits, however, is not clearly understood, and the presence of salines near some of the oil localities renders their classification by no means certain.

SYNOPSIS OF STRATUM OIL AND GAS STATISTICS.

ARRANGEMENT.

The saline domes were discussed in alphabetic order, for each structure of that type is separate and independent, without any connection whatever with similar structures of neighboring or distant districts. This arbitrary arrangement is inapplicable or at least undesirable for the stratum oil and gas occurrences, which have a direct, well-understood stratigraphic continuity from one field to another. The primal classification and subsequent arrangement of the statistics should be made on a stratigraphic basis. In a general way, even ten years ago, the division of eastern Texas petroleum products into Cretaceous and Eocene was often made and well understood. A surprisingly small amount of work has been done, however, in eastern Texas, in referring oil-bearing strata to definite stages or formations. Not one occurrence, so far as the writer is aware, has been so fixed beyond doubt. In view of these facts it seems most logical to treat, first, the comparatively well understood Cretaceous oil and gas horizons of Louisiana, then the ill-determined fields of Texas, and last the less important Eocene occurrences in the two States.

CRETACEOUS.

CADDO.

Location.—North-central Caddo Parish, La., 20 to 30 miles northwest of Shreveport.

Topography.—Low, undulating, slightly dissected stretches between the raft period Ferry Lake and Red River bottoms. Contains many of the much-discussed small "mounds."

Indications.—Gas escapes in pools of water and even in Caddo Lake.

History.—Gas piped to hut of pioneer and used for domestic purposes for several years before drilling was undertaken; this, with indications mentioned above, led to drilling.

Development.—Savage, Morrical & Savage erected first derrick, May, 1904; high-grade oil (35° to 37° B.) at length found at depth of 1,556 feet; subsequent development slow on account of the lack of great gushers. Gas in great quantities, under great pressure, at several horizons, causing notorious blow-outs, "burning wells," and "geysers," and making the district unhealthful. About two hundred wells drilled to close of 1908, producing in 1908 one-half million barrels of oil and furnishing Shreveport and Texarkana gas for all fuel purposes. Most of the gas wells capped, but 70,000,000 cubic feet let run to waste daily.

Area.—Oil development covering about 23 square miles; gas nearly twice that area.

Geology.—Field located on the north corner of Sabine uplift (see fig. 1); all oil and gas from Upper Cretaceous; main gas horizon now used, Nacatoch; gas and oil of light gravity, in Annona chalk; main oil horizon, light and heavy oil, Woodbine sand, depth 2,100 to 2,300 feet. See section (p. 30).

Generalized section of Caddo field.

System and series.	Formation.	Kind of material.	Approximate thickness. Feet.	Approximate depth. Feet.
Quaternary.		Red and gray sand, clay, gravel.	20	20
Tertiary (Eocene series).	Wilcox ("Sabine") formation.	Dark lignitic sands and clays, with calcareous bowlders.	430	450
	Midway formation.	Dark clay, with a limestone bed here and there.	200	650
Cretaceous (Gulf series).	Arkadelphia clay.	Dark stiff clay.	150	800
	Nacatoch sand.	"Shreveport" or "Caddo" gas sand; contains some hard layers.	130	930
	Marlbrook marl.	Blue marl, with chalky layers ("Saratoga" chalk member) at about 1,150 feet.	350	1,280
	Austin group. Annona chalk.	Chalky layers with many fossil fragments, often with strong odor of oil. Occasionally good oil at about 1,575 feet. Gas common.	320	1,600
	Austin group. Brownstown marl.	Clay, chalk, and sand, with hard pyrite layers.	200	1,800
	Eagle Ford clay.	Blossom sand member. Gas at 1,800 feet.	50	1,850
		Blue tough clays, with hard limestone and pyrite layers.	350	2,200
	Woodbine sand.	Sand beds at depths ranging from 2,140 to 2,300 feet, according to local structural features. They contain the "deep" oil and gas of the Caddo fields. Salt water common.	100+	2,300+

Oil and gas.—Gravity of oil from first gas sand, Nacatoch sand, 21° B.; Annona chalk, 37°-39° B.; Woodbine sand, 22°-43.5 B. See analyses, page 131. Gas, methane, 95 per cent; nitrogen, 2.56 per cent; carbon dioxide, 2.34 per cent.

References.—Oil Inv. Jour., November 6, 1908, p. 18. Iowa Geol. Survey, Bull. No. 8. For general geology of northwestern Louisiana and adjacent territory, see Prof. Paper U. S. Geol. Survey No. 46.

MINOR LOCALITIES IN ARKANSAS AND NORTHEASTERN TEXAS.

Hope, Ark.—A. P. Dyke's test well, south of Hope, reported as setting casing in limestone at 800 feet. (Oil Inv. Jour., June 6, 1909.)

Texarkana.—Blow-out recorded in test well north of Texarkana December 6, 1908. J. D. Cook well, on College Hill, 2,300 feet deep with some gas. (Oil Inv. Jour., December 19, 1907.)

Sulphur Springs, Tex.—A 1,500-foot well noticed in Prof. Paper U. S. Geol. Survey No. 46; no mention of oil or gas indications.

Cobbs Switch, Tex.—Test wells sunk here and pronounced dry. (Oil Inv. Jour., September 19, 1907.)

CORSICANA.

Location.—Central Navarro County, eastern Texas. (See fig. 1.)

Topography.—Practically a plain, but slightly dissected.

Indications.—None at surface; oil in water well at 1,027 feet.

Development.—Oil discovered by Maj. Alex. Beaton about or somewhat prior to 1894, in water well at 1,027 feet; well sunk to 2,470 feet, but oil came up around casing. First well put down for oil 200 feet south of water well, 1895; yields 2½ barrels daily. First well of importance sunk, 1906; yields 22 barrels daily. Refinery erected, 1898, utilizing production of 62 wells then producing. Gas utilized in the town for fuel purposes. Greatest yield, 1900, 829,560 barrels; steady decline thereafter.

Area.—From 12 to 15 square miles, elliptical in shape, longer axis trending northeast-southwest.

Geology.—Oil found highly siliceous, soft gray shale at a depth of approximately 1,050 feet, bed dipping southeast, 53 feet to the mile; horizon above Austin group, but whether Navarro or Taylor (corresponding roughly with Nacatoch and Marlbrook) not yet determined. Slight differences in character of the "sand" and minor folds cause great variations in production of various wells, as in the Caddo field.

Oil and gas.—Thiele gives for Corsicana oil, naphtha, 10.8 per cent; kerosene, 54.5 per cent; residue, 34.7 per cent; gravity, 0.8206. Of 1,015 wells in 1900, but 27 were classed as gas wells; gas found also somewhat outside of oil territory; pressure in places 200 pounds a square inch.

References.—Univ. Texas Min. Survey, Bull. No. 1, pp. 6, 36. Bull. U. S. Geol. Survey No. 184, p. 38.

POWELL.

Location.—Eastern Navarro County, Tex., 8 miles east of Corsicana.

Development.—Field opened in September, 1900, and that year produced the greater part of the 6,479 barrels of heavy oil accredited to the State of Texas. Year of greatest production was 1906—673,221 barrels; a steady decline thereafter.

Geology.—Oil generally conceded to come from higher horizon than Corsicana output; beds also dip eastward; depth of wells from 700 to 1,100 feet.

Oil.—Classed as heavy, ranging in gravity from 23° to 28° B.

References.—Univ. Texas Min. Survey, Bull. No. 1, p. 39. Bull. U. S. Geol. Survey No. 184, pp. 54–55. Oil Inv. Jour., January 3, 1906.

RICE.

Remarks.—Ten miles north of Corsicana, Tex., near Rice, a small amount of light oil (38° B.) is obtained; it is evidently the geologic equivalent of the oil from the "sand" at Corsicana.

SOUTH BOSQUE.

Location.—Near Waco, McLennan County, Tex.

Remarks.—Small oil field discovered by a Mr. Prathers in shallow-water well on the Bosque, 1890. Oil rich in paraffin; 26 wells in 1908 produced 5,200 barrels. See page — for total output of field.

References.—Oil Inv. Jour., January 19, 1908; February 6, 1909.

ELGIN AND VICINITY.

Remarks.—Three 300 to 400 foot wells near Elgin, reported as furnishing good lubricating oil from Cretaceous strata. Three similar wells near Lockhart. Caldwell produced similar results (Univ. Texas Min. Survey, Bull. No. 1, p. 36). A well in the Davilla field in Milan County near the Bell County line is reported as a failure (Oil Inv. Jour., July 5, 1907).

SAN ANTONIO AND VICINITY.

Remarks.—Some oil reported from water wells in San Antonio, 500 feet deep; Dullnig wells, 7 miles south of San Antonio, produced 48 barrels in 1889; oil known from wells 10 miles southwest of San Antonio. Twelve miles south of San Antonio wells between 1,000 and 1,100 feet deep, drilled in 1906 and 1907, furnish 3 barrels daily; one shows rock pressure of 180 pounds. Calaveras, Wilson County, 20 miles southeast of San Antonio, has "showing" of oil at 750 feet.

References.—Univ. Texas Min. Survey, Bull. No. 1, pp. 4, 50. Bull. U. S. Geol. Survey No. 282, p. 92. Oil Inv. Jour., February 19, 1908, p. 4; March 5, 1907.

EOCENE.

Indications of oil and gas are found at intervals from Sabine Parish, La., to the vicinity of Laredo, Tex., on the Rio Grande, along the outcropping belt of the Claiborne or mid-Eocene beds. To this geologic horizon, perhaps, some of the gas and oil occurrences may be referred with as much assurance as the various Cretaceous oils have been correlated with certain horizons in that system. But too little is known regarding the geologic details of most of these Eocene localities to admit of positive and final reference. Moreover, the presence, known or suspected, of saline domes in close proximity to the oil and gas occurrences thus far known in the Eocene formations tends to give the impression that these may be seepages from Cretaceous rocks several hundred, if not several thousand, feet below.

LINCOLN PARISH, LA.

Waterworks well and Ruston Oil and Development Company test well at 785 feet pass and case off a "sand" yielding 5 or 10 barrels a day; the Ruston well obtained nothing below to depth of 1,879 feet (Oil Inv. Jour., Ausust 23, 1907). As fossils coming from this well at depths of more than 700 feet are of Claiborne age, there is little reason for supposing that there is here an oil-collecting uplift in underlying Cretaceous strata, as in the Caddo field.

SABINE PARISH, LA.

Negreet.—Two or three miles southwest of Negreet about half a dozen shallow wells, sunk by Doctor Foster, yielded small quantities of oil and gas; the Producers' Oil Company is reported to have taken the matter in hand for future exploitation.

Columbus.—Near Columbus, in sec. 12, T. 4 N., R. 12 W., J. M. Guffey put down a well 500 feet, July, 1906. One-fourth mile from this well, on Chris Anthony's farm, a gas "showing" was reported between 400 and 500 feet, February, 1909.

Fort Jessup.—Near Fort Jessup the Sabine Valley Oil Company "twisted off" at 1,375 feet after passing oil showing at 1,200 feet. This prospect is near the old hole drilled by Mrs. Van Epps about five years ago, known as the Fort Jessup Oil Company test, which was abandoned after reaching a depth of 1,568 feet on account of a twist-off that could not be fished out. P. M. Schuman did the drilling (Oil Inv. Jour., July 6, 1909).

VERNON PARISH, LA.

Leesville.—Test well at Leesville by Beaumont people reported at a depth of 960 feet August 4, 1909.

SABINE COUNTY, TEX.

East Texas Oil and Timber Company's 1,250-foot test well near Sabine River, 1 mile below Robinsons Ferry, found no encouraging indications (Prof. Paper U. S. Geol. Survey No. 46, pp. 37, 324).

ANGELINA COUNTY, TEX.

Vicinity of Lufkin well exploited during past five years. Layne & Fowler encountered oil "showings" at about 1,200 feet. Same showing found in O'Brien well, but was cased off and well deepened to 1,700 feet without favorable results, July 20, 1909.

NACOGDOCHES COUNTY, TEX.

Location of oil field.—From 14 to 18 miles southeast of town of Nacogdoches.

Topography.—Two groups of wells, one in the valley of Mast Creek, the other about 2 miles to the southwest, in the bottom lands of a tributary of this creek, at Oil City.

Indications.—"Boiling water," caused by the escape of gas; iridescent films on the surface of the water; sulphureted waters.

Development.—Discovered in 1867; few wells sunk till 1887; 90 shallow wells put down between 1887 and 1890. First pipe line in Texas, about 14½ miles long, connected this field with town of Nacogdoches. Field practically abandoned of late; Higgins Oil and Fuel Company's 2,000-foot well (1907) showed no "indications" below 285 feet.

Area.—Most of the wells in two groups, each occupying nearly a square mile.

Geology.—Predominant surface rock greensand of Claiborne (mid-Eocene) age, in places weathered reddish; oil apparently in similar, somewhat pervious beds between clayey layers; wells 70 to 200 feet deep; local heavy dips abundant.

Oil.—Heavy (0.9179 at 62.6° F.), asphaltic, similar to saline-dome oil, used for manufacture of lubricants.

References.—Univ. Texas Min. Survey, Bull. No. 1, pp. 1-5. Bull. U. S. Geol. Survey No. 282, pp. 70-72. Oil Inv. Jour., June 19, 1907.

Cushing.—In northern Nacogdoches County, at Cushing, a test well was recorded in rock at 850 feet, July 20, 1908.

ANDERSON COUNTY, TEX.

Palestine.—At Palestine water wells 500 to 600 feet deep show no signs of oil or gas; but 10 to 12 miles east three shallow wells afforded some heavy oil (Oil Inv. Jour., August 20, 1908).

BURLESON COUNTY, TEX.

Caldwell.—About 16 miles southeast of Caldwell, Mound Prairie Oil and Gas Company report indications of oil at 400 feet, but nothing below to bottom of well. 2,000 feet (Oil Inv. Jour., June 19, 1907).

GONZALES COUNTY, TEX.

Ottine.—Vicinity of Ottine has been much prospected; before 1906 nine wells were sunk within 3 miles of town; some oil obtained from shallow wells; gas reported abundant at 900 feet. This field is remarkable for showing "mounds" in process of formation. Heywood Company test well is 1,630 feet deep on Brown Company's land (Oil Inv. Jour., November 19, 1907). Now being deepened by Producers' Oil Company.

WEBB COUNTY, TEX.

Aguilares.—North of Aguilares, 30 miles east of Laredo, a 5,000,000-foot gas well reported; pipe line contemplated to Laredo (Oil Inv. Jour., December 20, 1908).

Remarks.—Too little is known regarding the stratigraphy of the geologic formations in southern Texas along the Rio Grande to admit of drawing any well-founded conclusions regarding probable locations of oil and gas fields. But the extraordinary broadening of the Claiborne beds along this river, the size of the gas well at Aguilares, and the presence of a well-defined salt dome at Piedras Pintas, in Duval County, not far to the east, at least suggest a striking parallelism with the Sabine uplift in northwestern Louisiana, with scarcely no southern dip for 100 miles and with its great gas wells and saline domes to the east.

PRODUCTION.

Production of stratum oil fields in Louisiana and eastern Texas.[a]

Year.	Corsicana.	Powell.	South Bosque.	Caddo.
1896	1,450	....	....	....
1897	65,975	....	....	....
1898	544,620	....	....	....
1899	668,483	....	....	....
1900	829,560	6,479	....	....
1901	763,424	37,121	....	....
1902	571,059	46,812	....	....
1903	401,817	100,143	....	....
1904	374,318	129,329	....	....
1905	311,554	132,866	....	....
1906	332,622	673,221	1,300	4,650
1907	226,311	596,897	8,000	48,266
1908	211,335	398,649	5,200	513,504
	5,302,528	2,121,517	14,500	566,420

[a] From Oil Investors' Journal, February 6, 1909.

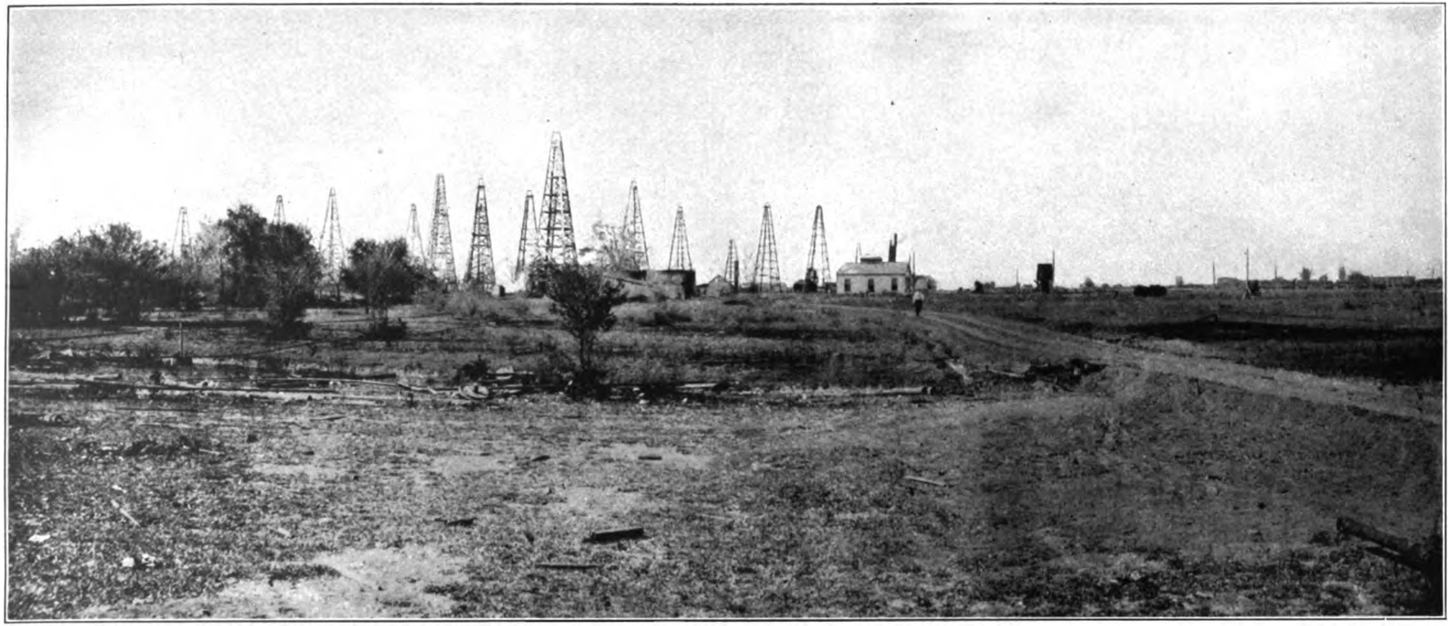
DETAILS OF OIL AND GAS FIELDS AND PROSPECTS IN LOUISIANA.

SALINE-DOME FIELDS AND PROSPECTS.

ANSE LA BUTTE.

Location and topography.—The Anse la Butte field is located on the highway between Lafayette and Breaux Bridge, about 6 miles from the former and 3 from the latter, in St. Martin Parish. About 3 miles to the east, flowing southward, is the navigable Bayou Teche; about 1 mile to the west is the smaller stream, Bayou Vermilion, flowing likewise in a southerly direction. Between the borders of the main streams (the bayous) and the various smaller streams (the coulées) the country is a very slightly rolling prairie. Except for the "butte" itself, the field is remarkably low, only a few feet above sea level. (See contours on map, Pl. II, also Pl. III.) Temporary bench marks on a line of approach to the field from Lafayette or Breaux Bridge serve to emphasize this fact.

	Feet.
Lafayette, top of rail, Southern Pacific Railroad station	40
First angle in road, one-half mile northeast	39.2
Third angle, 1½ miles east	39.9
First small coulée bridge, 2 miles east, floor	31.5
Big bayou, between fourth and fifth angles in road, 3 miles east:	
Top of bridge railing, right side going east	27.2
Water	22.3
Long bridge over overflow channel one-half mile west of Bayou Vermilion bridge, floor	15.5



ANSE LA BUTTE OIL FIELD, LOOKING NORTHWEST.

The swamp underneath which the solid rock-salt dome is located may be seen at the extreme left; the low "butte" lies immediately beyond, hidden by foliage; the curved outline of the depression, the cove, the "anse" and the slight elevation, the "butte," gave the field its name. Most of the successful wells are located centrally in the group of derricks shown. An "air plant," the Lafayette and Baton Rouge branch of the Southern Pacific Railroad, and loading racks can be seen at the right.

	Feet.
Bayou Vermilion bridge:	
Floor	15
Water, January 6, 1903	10.6
January 15, 1909	4
Nail head in gum tree cut off for gate post, entrance to oil field	18.7
Bayou bridge 1 mile east of oil field, floor	13
Railway, top of rail	25.6
Breaux Bridge railroad station, top of rail	27.5

History.—The first references to any serious effort to develop the mineral resources of the Anse la Butte field have been kindly furnished by Mr. Charles S. Babin, jr., of Lafayette, La. It appears that as early as April 4, 1893, Mr. Babin was appointed special agent to "sell, rent," or in any way advantageously manage the "mines" of "coal, oil, sulphur, iron, gas, or whatever else may be found" on the lands of Mrs. Emma Pelletier (42 arpents) and Honoré Breaux (40 arpents). Interest in the field was aroused solely on account of the quantities of inflammable gas that came out from the marsh lands surrounding the principal "butte." Paul Ledanois was the first to attempt boring, with the aid of a machinist, but he encountered some difficulties, and at a depth of 40 or 50 feet discontinued the undertaking. In 1899, as shown in Plate XI of the Louisiana State Survey report for that year, two iron pipes thrust into the ground for a few feet at this locality conducted gas to a height of 6 or 8 feet, where it was lit and at night furnished light for a local gathering. During the same year Capt. A. F. Lucas was on the ground attempting to drill an oil well in spite of poor tools and meager financial support. He soon left for Beaumont, Tex.

The finding of oil at Spindletop early in 1901 caused renewed activity at Anse la Butte. The Moresi Brothers, of Jeanerette, drilled their Pioneer well during the fall of that year. During the following summer they drilled their No. 1 close to the "swamp." Heywood No. 1, on the north side of the swamp, very near the point where the gas had always been most noticeable at the surface, was the first to show that oil existed in considerable quantities at Anse la Butte. However, the extreme fineness of the sand was supposed to be an insurmountable obstacle in the way of oil production, and the Heywood rig was moved over to No. 2, on the south side of the swamp, but met with no marked success. The rig was then moved back to No. 1, the well was bailed, and for the first time a clear stream of oil gushed 25 feet high, convincing that a new oil field had been discovered.

Wells of less than 100 barrels were brought in now and then for the next few years, but little attention was given to Anse la Butte till late in 1907 (November 14), when the Lake Oil Company brought in its No. 7, with an initial capacity between 3,000 and 4,000 barrels daily. In spite of the fact that enough drilling had been done about the field to show that it was an extremely local uplift with a salt core coming very close to the surface and with exceedingly steep local dips immediately about this core, old oil producers invested heavily and commenced putting down wells as far as three-fourths of a mile from the swamp. The failure of such undertakings, together with the growing importance of other fields, notably Caddo, caused attention again to be directed elsewhere. However, the Lake Company has put down 16 wells in all, most of which have been producers. Nearly all the successful wells have been within less than 500 feet from the swamp. So far as the writer is aware none more than 900 feet from the swamp can be classed as producers.

Structural features.—Study of the local salt masses in Louisiana and eastern Texas[a] proves that the very presence of such material in any considerable quantity indicates a pronounced dome structure with quaquaversal dip. The drillers speak of "drilling a little distance away from the swamp, where the strata are less disturbed." Fenneman remarks:[b]

> A 6-inch core of rocks taken from one of the wells on the east side of the swamp shows markings which are inclined at a high angle, presumably toward the southeast. These lines have been supposed by some to represent bedding and therefore to indicate a pronounced uplift near the center of the field. From an examination of the core referred to the inference is believed to be not wholly established. The markings resemble joints or fractures which have been recemented quite as much as bedding planes.

Even if the correctness of this inference is granted (though the writer believes it incorrect) there still remains the necessity of admitting some very serious disturbances whereby solid rocks could be shattered along planes dipping 45°.

Lake Grow continued to obtain good oil from Lake well No. 9 when No. 7 had practically gone to salt water, even though No. 9 was drawing from a slightly deeper level than No. 7. Evidently the two wells were not yielding oil from the same bed; the upper, outer bed was being flooded with salt water, while the lower, inner one was still bearing oil.

A bed of very characteristic univalve shells was encountered in Grow well No. 1 at a depth of 1,920 feet, and in Lake well No. 8, 100 feet nearer the swamp, at 1,910 feet, showing a dip to the north of 1 in 10. The top of the oil sand in Lake No. 9 is at a depth of 1,841 feet; in No. 6, 7 feet to the northeast, it is at 1,848 feet, showing a northeasterly dip of about 1 in 11. Hard rock cores brought up in Lake No. 2, according to Mr. Grow, proved a dip of 10° away from the swamp. The heavy gravel bed extends in Lake No. 9 to a depth of 460 feet; in Grow No. 1, but 370 feet away, it extends to 620 feet. The André Martin well, on the south side of the swamp, is said to have passed through very much disturbed salty masses. The Deborah wells are reported as passing through great rock masses at comparatively shallow depths. A slight distance from the swamp, however, the beds are probably quite horizontal. The Guffey and the Heywood No. 8, drilled at about the same time, are reported to have passed through the same kinds of material at the same depths.

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[a] Bull. Louisiana Geol. Survey No. 7, 1907.

[b] Bull. U. S. Geol. Survey No. 282, 1906, p. 109.

Central salt mass.—Salt in a somewhat disturbed condition occurs in the André Martin well on the south side of the swamp at depths from 245 to 1,530 feet, the bottom of the well. Salt has also been struck in at least one of the wells on the southeast margin of the swamp, but exact data regarding depth are not available. From Louisiana well No. 2 (see map, Pl. II) no salt has been reported. Lake No. 4, on the north side of the swamp, passed through alternating beds of salt and gypsum from about 375 to 2,187 feet, the bottom of the well. Heywood No. 1 went through salt between depths of 268 and 540 feet, and again between 1,350 feet and the bottom of the well, 1,550 feet. In the original Lucas well a bed said to contain some salt was encountered at 290 feet. Salt is reported as extending from 283 feet for about 100 feet in Anse la Butte No. 2, again at 1,600 and at 1,784 feet, but at 1,910 feet occurs an "oil sand" that has yielded 30 barrels a day on air pressure. The Martin-Simpson well on top of the hill passes through salt from 390 to 570 feet and again from 578 to 790 feet, below which, strangely enough, sand and gravel are reported. According to Fenneman, the Sharp well entered salt at 220 feet and continued in it to the bottom at 1,803 feet. It is true that well sections obtained from various sources from one to six or eight years after the wells have been put down are unreliable, and many of the figures given above are doubtless wrong, and so likewise may be the sections given in figure 3. Nevertheless, certain general conclusions can be drawn from them as a whole. No salt appears in the Lake No. 9, only 300 feet from the margin of the swamp. The record of Lake No. 11 is not at hand, but salt is reported in both Anse la Butte No. 2 and Heywood No. 1, as stated above. From the records of the Sharp, Martin-Simpson, Anse la Butte No. 2, Heywood No. 1, and Lake No. 4 (fig. 3, a), it is evident that in general the nearer the swamp is approached the more salt is encountered. Figure 3, b, shows the supposed stratigraphic relations of the beds between Lake No. 4 and Anse la Butte No. 2.

Plate IV gives four well sections from the north edge of the swamp northward for about 650 feet. These show conclusively how impossible it is to predict the depth of "pay sand" at any given locality. Aside from the gravel and sand stratum near the top of each section, there is nothing that can be traced with certainty from well to well.

Plate V shows sections of wells south, east, and north of the swamp at distances varying from one-fourth to one-half mile. These wells show a general preponderance of clay beneath the superficial gravel and sand. Owing probably to a lack of care in taking samples frequently, the sections of the Moresi No. 2 and Pioneer doubtless indicate less sand than these wells really contain. The Heywood-Sharp well, near the north limit of the area mapped on Plate II, was drilled by H. H. Jones, who is unusually careful in his log records. The section compiled from his records doubtless represents the usual run of sand and clay beds in this portion of the State.

Occurrence of oil.—Coarse, shallow sands on the southeast side of the swamp have furnished a small amount of oil for the past six years. Heywood No. 2 showed oil sand at 400 to 485 and 570 to 593 feet. This well was drilled in 1903. The New Iberia Petroleum Company's well (740–760 feet) was finished in January, 1909, and furnished in February 50 barrels daily on air pressure. Moresi No. 1 gave salt water at 1,150 feet; Heywood No. 8 furnished 5,000 barrels of salt water at 2,406 feet; Heywood No. 11, credited with a depth of 840 feet, furnished for over a year about 100 barrels of oil daily, together with 800 barrels of salt water; Heywood No. 12 tested salt water at 1,100 and 1,300 feet, and was abandoned in April, 1908.

The Deborah wells, on the south side of the swamp, have all been abandoned, so far as can be learned at depths ranging from 600 to 1,000 feet, on account of salt water. Deborah No. 3 showed very favorable signs of being a producer at about 900 feet when the writer visited the field in November, 1908.

Heywood No. 1 furnished oil through a slit in the casing at about 1,000 feet from an oil pocket caught under a salt mass. (See fig. 3, *B*.) The original Lucas well showed some oil between 250 and 350 feet. Anse la Butte No. 2, 1,910 feet deep, furnished in February, 1909, 30 barrels of oil and 300 of salt water daily.

Lake No. 7 is said to have penetrated 30 feet of oil sand between 1,835 and 1,865 feet; above the sand are "regular formations with much good gumbo." The 6-inch casing was set at 650 feet and the well drilled with a diameter of 4 inches the rest of the way. The Oil Investors' Journal remarks (vol. 6, No. 12, p. 1):

> Ordinarily it would be considered next to impossible to complete a well with one string of pipe and shut off the water as has been done in the case of this hole. It is stated that the strainer—No. 40 Keystone— was screwed onto the 4-inch pipe and a gunny sack wrapped around the top of the screen to make a tight joint above the sand. The wash pipe was lowered into the well, and when the upper portion of the strainer had been cleaned out oil appeared, going over the derrick.

This was November 14, 1907. This well flowed for ten days, making from 3,000 to 4,000 barrels daily, but on November 24 stopped for half an hour, then flowed again by heads. It then made 2,400 to 2,700 barrels daily, including fine sand and about 35 per cent of water. The temperature of the oil was 130° F.; it tested 22.5° Baumé when re-

duced to 60° F. Three months after this well was drilled it was producing about 1,300 barrels daily of liquid, about half of which was oil.

The success of Lake No. 7 in the so-called "deep sand" was the signal for the commencement of extensive operations in this field. Besides a great amount of "wildcatting" in surrounding territory, old wells were cleaned out and deepened. Among those so operated may be mentioned the Lake No. 6, a small producer, from a depth of 1,800 feet. The record of the lower portion of this well, from the field manager's notes, is as follows:

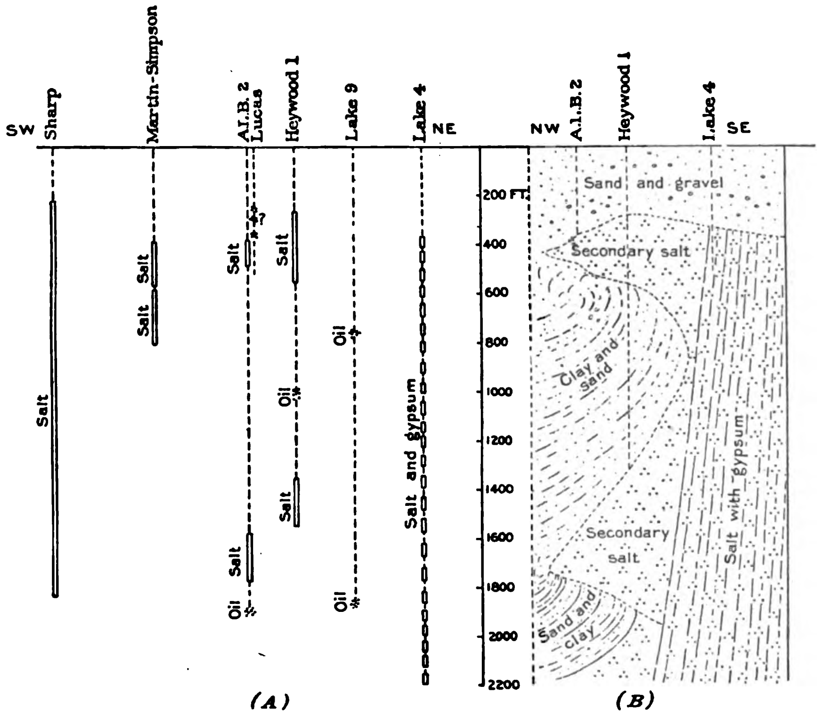

FIGURE 3.—*A*, Sections near the northern margin of the salt mass, Anse la Butte. *B*, North margin (hypothetical) of salt mass at Anse la Butte.

Log of lower portion of Lake well No. 6, Anse la Butte.

	Feet.
Hard sand	1809–1811
Gumbo	1811–1821
Shale	1821–1826
Rock	1826–1828
Gumbo	1828–1832
Oil-bearing clay	1832–1841
Rock	1841–1848
Oil sand	1848–1889

Stopped 8 inches in hard rock.

This well made 1,765 barrels the first day with little water. It rapidly grew salty, and in a few days was producing only about 500 barrels of oil. The oil is described as "steaming hot."

Lake No. 8, though carried to a depth of more than 2,000 feet, going through much "rock" from 1,000 down, is still, so far as can be learned, unproductive.

Lake No. 9 started off at the rate of 300 barrels daily, but soon dropped to 60 barrels of oil and 250 barrels of salt water. (See section Pl. IV.)

Lake No. 10 commenced flowing September 11, 1908, at an estimated rate of 4,000 barrels daily, but soon dropped to 1,500 barrels with an equal amount of salt water. This well, No. 11, and No. 12 appear to be shallower than No. 7, though exact data on the subject are not at hand. In amount and manner of production they seem to be very much alike.

Gas.—Strong gas pressures have been recorded in several wells in the field and some distance away. Heywood No. 1 was a famous "gasser." It would roar for hours, throwing water and sand 225 feet high. The Martin-Simpson well, on top of the hill, is supposed to have shown a pressure of 700 pounds at a depth of 800 feet. Lake No. 5 was a famous "gasser," and the gas took fire and destroyed the derrick. Heywood No. 8 found good gas at 1,300 feet. The Heywood & Guffey well, on the Louisiana Petroleum Company's lease, reached a porous gas rock at 800 feet that produced a large amount of gas, blowing water and sand out in great quantities, burying the machinery 5 feet deep.

Few other wells within 1,000 feet of the swamp and none outside that limit are economically important.

Conclusions.—The conclusions of the present writer regarding the occurrence of oil in this field are that within 500 feet of the edge of the swamp all the underlying beds are badly disturbed, being in many places more nearly on edge than in a horizontal position. This disturbance of beds that were doubtless deposited more or less horizontally is believed to be due to the upthrust of the central salt mass, as described in Bulletin No. 7 of the Louisiana State Geological Survey. The presence of oil in the central portion of the field near the swamp and its absence even at great depths in the adjacent surrounding territory afford proof of a dome structure in the field. Again, the high temperature of the oil speaks clearly for its very deep-seated origin. The oil is evidently coming up through porous layers to places where these layers have been cut off or pinched out by the disturbance just referred to. In some places in close proximity to the central salt mass oil pockets are found beneath bodies of salt, as indicated by figure 3, *B*.

The writer has continually held, publicly and privately, that there is practically no hope of finding oil a few hundred feet away from the margin of the swamp. Drilling about the field has amply justified this position. That the edges of porous, oil-bearing sand beds truncated by impervious layers lie about the field within less than 2,000 feet of the surface there is little doubt. Systematic investigation on all sides of the field with a large amount of capital would probably result in considerable profit, but mere haphazard drilling anywhere within a mile of the field is a waste of money.

Production.—As tabulated by the Oil Investors' Journal, the production of the Anse la Butte field has been as follows:

Production of oil in Anse la Butte field, 1905–1908.

	Barrels.
1905	9,000
1906	23,708
1907	76,938
1908	219,265

Storage.—Besides the four steel tanks in the field and the small earthen one, as shown on the map (Pl. II), the Gulf Pipe Line Company prepared a 100,000-barrel earthen tank 1½ miles east of the field.

Pipe lines.—The Heywood Brothers Oil Corporation and the Lake Oil Company had a 4-inch pipe line completed to Breaux Bridge in March, 1906. Both barges and cars are loaded at that point.

The Evangeline 4-inch pipe line, but 1,500 feet from the field, passing from Jennings to the Atchafalaya, was connected with the Lake Company's wells in November, 1907.

Loading rack and transportation facilities.—A 20-car loading rack was established on a siding on the Baton Rouge branch of the Southern Pacific Railroad passing through the field. Motor-car service over this line to the field from Lafayette continued but a few months in 1907–8.

BAYOU BOUILLON.

Location.—The locality usually designated Bayou Bouillon in oil and gas publications is at the junction of Bayou Bouillon with Atchafalaya River, about 30 miles northeast of New Iberia. A few years ago a small boat made regular trips to this place from the crossing of the Atchafalaya at Melville, on the Texas and Pacific Railway, down that river to Bayou Bouillon or Larumpe. Large steamers reach this place by way of the Atchafalaya from Morgan City.

History and geology.—Early in the summer of 1902 Maxwell & Sherwood erected a derrick on the west bank of Atchafalaya River, on what seemed to be the line of the strongest gas escapes. Their site was characterized by a Spindletop-like mound. On the opposite or east side, also along the line of gas seepage and on a mound, the Heywood

Brothers Oil Corporation soon afterward had a derrick erected. By July 1 the Maxwell & Sherwood well was in rock at a depth of 350 feet, with good oil "showings" in many places. Before the end of July Heywood Brothers had reached a stratum 10 feet thick, from which they obtained several bucketfuls of oil. Other wells were put down in this vicinity, but so far as known only three ever reached depths of more than a few hundred feet. Some details of these wells, as given by Fenneman,[a] are as follows:

> Samples of the gas were analyzed by Professor Metz, of Tulane University, who finds 93.72 per cent to be hydrocarbons. It is not stated what proportion of the whole is marsh gas. Professor Metz finds no hydrogen sulphide, which is so common a constituent of the gas of the Texas oil fields. The gas is very similar to that which is found elsewhere in the delta and coastal region of Louisiana.
>
> The oil, which has been found in small quantities at shallow depths, has also been analyzed by Doctors Metz and Eustis. It is of a dark-brownish or black color, very viscid, and having a specific gravity of 0.859. The fractional distillation of this oil resulted as follows:

Fractional distillation of oil from Bayou Bouillon, Louisiana.

Temperature.	Product.	Percentage by volume.
Below 150° C.	Chiefly water	4.3
Below 300° C.	Illuminating oil	28.4
Above 300° C.	Lubricating oil	42.0
	Asphalt and coke	15.5
	Loss	9.8
		100.0

> The few logs obtained, though taken from wells not far apart, are very different. This diversity may be supposed to indicate that no one bed has any considerable lateral extent. If this be true, it may be inferred that no large oil body could be retained below the horizon protected by the surface clays and above the depth at which the wells stopped. From the meager data at hand it is not possible to state positively that the continuous clay beds which are necessary as cap rocks are wanting, but the amount of clay reported in the Maxwell & Sherwood well is very small. There is frequent mention of clay mixed with sand, but the beds distinguished as pure clay are never more than 5 feet in thickness. Under such beds a showing of oil was generally noted. A 300-foot limestone is reported in this well between the depths of 850 and 1,150 feet. The Shelbourne well, whose log is given below, shows much more clay or gumbo. A stratum 173 feet thick was encountered at a depth of 390 feet, and most of the material between that depth and 810 feet is clay or contains a considerable admixture of clay. In each of these wells a number of thin plates of rock were passed. In another well, not specifically named, a sandy bed between 1,200 and 1,280 feet yielded salt water said to be hot enough to burn the hand.

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[a] Bull. U. S. Geol. Survey No. 282, 1906, pp. 112-113.

Logs of wells on Bayou Bouillon, Louisiana.

SHELBOURNE WELL.

[Received from Mr. Robert Martin.]

	Formation.	Thickness.	Depth.		Formation.	Thickness.	Depth.
		Feet.	*Feet.*			*Feet.*	*Feet.*
1	Clay	62	62	13	Hard gumbo	21	632
2	Sand	176	238	14	Soft gumbo, with some gas, showing a little oil	24	656
3	Hard gravel and sand	10	248	15	Gumbo	24	680
4	Fine sand and gravel	50	298	16	Very soft gumbo	55	735
5	Rock	4	302	17	Gumbo, with fine gravel and shells	27	762
6	Sand	28	330	18	Rock	1	763
7	Heavy gravel	2	332	19	Gumbo, with gas and some showing of oil	17	780
8	Rock	2	334	20	Rock or hard gravel	4	784
9	Sand	56	390	21	Sand and gravel, showing oil	36	820
10	Gumbo	173	563				
11	Gumbo, gravel, and pockets of gas, showing some oil	43	606				
12	Gumbo	5	611				

MAXWELL & SHERWOOD WELL.

1	Sand	5	5	22	Sand and gumbo	4	311
2	Red clay	15	20	23	Sand and gravel	6	321
3	Gumbo and sand	80	100	24	Sand	10	331
4	Gray sand and gas	5	105	25	Sand showing oil	6	337
5	Sand and clay	58	163	26	Small gravel	8	345
6	Gravel and shell	3	166	27	Gravel and gumbo	14	359
7	Gray sand	4	170	28	Small gravel	30	389
8	Fine sand and gumbo	38	208	29	Gumbo, gravel, and sand	81	470
9	Rock	2	210	30	Gumbo	3	473
10	Sand	4	214	31	Coarse gravel	134	607
11	Gravel	14	228	32	Gumbo and fine gravel	20	627
12	Gumbo	3	231	33	Sand	30	657
13	Coarse white sand showing oil	8	239	34	Gravel and gumbo	30	687
14	Fine sand showing oil	4	243	35	Coarse gravel	10	697
15	Gumbo	1	244	36	Sand	30	727
16	Sand showing oil	9	253	37	Gumbo and gravel	20	747
17	Gumbo	2	255	38	Sand and gravel	70	817
18	Gumbo and sand mixed	18	273	39	Coarse gravel	20	837
19	Gravel	20	293	40	Rock (lime)	20	857
20	Sand	10	303	41	Coarse sand	300	1,157
21	Sand showing oil	8	311	42	Sand	140	1,297
				43	Blue sand (rock)	265	1,562

Water was salty below 1,000 feet. From 1,150 to 1,200 feet water overflowed pipe.

In the fall of 1907 Robert Martin went back to deepen the old Heywood hole, and on December 5, 1907, was reported (Oil Investors' Journal) to have reached a depth of 1,200 feet and found showings of oil and gas. A year later another attempt was made to deepen an old hole and preparations were being made to sink a new well on the east bank of the bayou.

BELLE ISLE.

Location.—Belle Isle is located about three-fourths of a mile north of Atchafalaya Bay, in the midst of the low sea marshes about 8 miles west of the mouth of Atchafalaya River. It is well shown on Coast and Geodetic Survey chart No. 199.

Topography.—On the chart just referred to this "island" is shown with a quadrilateral aspect, the northwest side being the longest. The interesting topographic and geologic features of the island are in its northwestern portion. Here an elevated ridge, much contracted centrally, extends in a northeast-southwest direction for about three-fourths of a mile, here and there rising to 60 or even 80 feet above tide. The topographic details are shown on Plate XXI of the Louisiana Geological Survey report of 1899, and Plate XXV of the report of 1907.

Development.—The early history of the development of this island, up to the year 1899, is well given by Veatch.[a] The thirteen holes and shaft then put down by the Gulf Company he located and discussed, especially with regard to their bearing on the occurrence of rock salt. Another set of holes, designated A to J inclusive, were afterwards sunk and their important geologic features were pointed out in the Louisiana Geological Survey report for 1907, pages 76 et seq. In this same year (1907) the New Orleans Milling and Mining Company put down two deep wells on the northern margin of the island for the purpose of ascertaining its oil possibilities.

The investigations made on the island in 1907–8 by I. N. Knapp and associates consisted of sinking one well to the great depth of 3,020 feet near the first salt shaft and two others one-twentieth and one-half mile farther south; also of collecting all the data possible regarding the occurrence of rock salt in the wells thus far drilled and from them constructing a large-scale map indicating the contours of the underlying salt domes.

Geology.—A topographic ridge three-fourths of a mile long, extending along the northwest side of the "island," has already been mentioned. Underneath this ridge there is a salt ridge or series of salt domes with two or perhaps three noteworthy elevations. The most northeasterly, next the canal, has been most thoroughly investigated. The history and geology of the "shaft" next the canal and of the oil well designated I, near the southwest limit of this first salt dome, have been fully discussed in state reports, but the first Knapp well, 100 feet south of the old shaft, must be described here. The section is as follows:

Section of Knapp well No. 1, Belle Isle.

[From Mr. Knapp's section.]

	Feet.
Shale of varying hardness; at 75–80 feet went through old mine timber; at 100 feet pyrites showed	0– 114
Whitish limestone	115– 122
Shale	122– 128
Gravelly shale	128– 133
Hard lime	133– 142
Oil sand; oil at 143 feet	142– 145
Shale and specks of sulphur	145– 159
Hard streak of lime; gas from 150 to 160 feet	159– 160

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[a] Rept. Louisiana Geol. Survey for 1899, pp. 221-229, with map and figs.

	Feet.
Shale showing oil	160– 186
Blue clay; *Rangia cuneata*, fish bones, and lignite at 186–189 feet	186– 187
Rotten limestone	187– 200
Probably salt	200– 211
Salt of varied character	211– 912
Salt with strong oil odor and taste to 700 feet.	
Salt, impure, with anhydrite, 418–767 feet.	
Puff of gas, 838 feet.	
Anhydrite, 844, 864 feet.	
Salt, varied	912–1,790
Slight bubbling of gas at 1,090 feet.	
Gas enough to give flame 2 or 3 feet above 10-inch pipe at 1,348 feet; this gas has a strong odor of crude oil; does not react for H_2S with acetate of lead; came from salt dirty with black shale; similar gas at 1,423 feet; both the puffs of gas lasted for a couple of days and then died out.	
Clear, clean salt at 1,425–1,790 feet.	
Greenish shale; mixed salt, gypsum incrusting salt, also black sand at 1,800 feet	1,790–1,800
Impure gypsum; gas held in salt crystals, which give a crackling noise when dissolving	1,800–1,806
Gas sand	1,806–1,810
Impure gassy salt	1,810–1,840
Soft gypsum	1,840–1,850
Impure salt showing a little gas and oil	1,850–1,904
Probably impure salt; overflow frothing with gas and showing oil	1,906–1,965
White salt	1,965–2,030
White salt with gas and oil showing; dark amber oil at 2,100 feet	2,030–2,112
Bits of pyrite and lime	2,112–2,114
Opaque salt with puffs of gas; fine amber oil obtained by straining scum at 2,190 feet	2,114–2,190
Salt, varied, clear and white or opaque and dirty with gas; oil obtained by straining froth at 2,500 feet	2,190–2,520
Salt, particles of galena and pyrites of iron and copper	2,520–2,606
Salt, anhydrite, and sulphur	2,606–2,628
Salt, impure and crystal; varying hardness; good oil showing; puff of gas at 2,722 feet threw water up 20 feet	2,628–2,740
Black sand—magnetite	2,740–2,745
Gas throwing water up 40 feet in derrick	2,783
Dark-red oil in salt	2,900
Anhydrite	2,940–3,005
Bottom of well	3,050

The extreme abruptness with which the salt mass pitches off to the north from this locality is apparent when the logs of the two wells of the New Orleans Mining Company are examined. Though these wells are but 870 and 1,030 feet north and a little west from the Knapp well and go to depths of 2,411 and 1,740 feet, respectively, these wells show only normal coastal sands and clays. A few points relating to the deeper of these wells, as gathered from Mr. Knapp's blueprints, are as follows:

Partial section of New Orleans Milling and Mining Company's well No. 3 (location No. 10 of Knapp's notes).

	Feet.
First oil showing	1,396
Oil showing increasing	1,506
Big gas showing; good oil showing	1,584
Small gas showing	1,786
Small gas showing	1,930
Gas and oil in sand	2,190
Last 80 feet give pronounced oil showing	2,270
Biggest pyrite showing; good oil showing	2,389
Total depth	2,411
No salt reported in this well	

As Mr. Knapp's notes give a somewhat different version of the log of Well I than that published in the Louisiana report of 1907, they are given here.

Notes on Well I, Belle Isle (location No. 12 of Knapp's notes).

	Feet.
Hard rock, one-third sulphur	203
Salt	375
Salt, limestone, and oil sand	430
Quicksand	450
Sulphur and hard shale	485
Sulphur rock	503
Sand rock with showings of gas and oil	550
Salt	585
Hard material, no salt	655
Sand rock, showings of gas and oil	675
Improving showings of gas and oil	700
Flint rock of the hardest kind	735
Salt	840
Hard material	856
Material softer, good showing	1,010
Gas pressure; brown sand rock and blue shale containing oil; gas flame 25 feet high	1,165
Loose brown oil sand and slate	1,202
Bottom of 4-inch pipe	1,210
Gas blowout; oil showing improving	1,230
Increase in gas	1,375
Diamond drill installed	1,430
Rock salt	1,455
Iron sand; probable depth from sample left in bottle	1,550
Gas blew water out of well; oil showing on slush tank	1,575
Salt	1,625
Strong gas pressure; better oil showing	1,945
Salt, with showing of gas and oil to bottom	2,035
Total depth	2,359

Knapp No. 2, Belle Isle, was a comparatively shallow well, regarding which Mr. Knapp has furnished the following data:

Notes on Knapp well No. 2, Belle Isle.

	Feet.
Sand, gravel, clay, streaks of limestone to sulphur rock	0–290
Gypsum and sulphur rock	290–390
Sulphur, gypsum, and anhydrite, very porous	390–880
Salt	880–890

Remarks: Average sulphur, 7.5 per cent; best sample, 35 per cent; slight showing of oil at 390 feet, where porous rock began. Well was 430 feet southwest of first and about 100 feet southeast of the little blacksmith shop, in flat back of salt works.

Regarding well No. 3 Mr. Knapp writes:

> The third Belle Isle well is about 2,800 feet from the first on the salt dome, and about south from it, and 150 feet southeast from old farmhouse. I have no record of it in Philadelphia, but it is about as follows:

Log of Knapp well No. 3, Belle Isle.

	Feet.
Stiff clays	0–127
Streaks of sand, clay shale, gravel, wood, and wood fiber	127–460
Lime rock	460–475
Gypseous material, clay, and salt	475–550
Impure salt	550–620
Clear salt	620–800

Not a particle of oil or gas showed; nor any sulphur.

When the topographic features of Belle Isle, as shown on Plate XXI of the Louisiana Geological Survey report of 1899, are considered in connection with all known well sections in this field, it is evident that this saline dome is compound in structure and origin, that the upward-flowing saline solutions producing the dome in all probability found their exit from the deeply buried beds below through faults trending northwest-southeast and northeast-southwest, and that the old shaft and Knapp No. 1 are close to the fault-line intersection. (See general structural lines in southern Louisiana as shown on Pl. I of the present report.)

Mr. Knapp has frequently commented on the tendency of the drill to run laterally in well No. 1, as if trying to follow soft layers in a mass nearly on edge. This tendency is amply accounted for by the concretionary growth of this saline mass as a whole, for where the materials are so various a vertical section near the outer shells of this mass might well show vertical seams, and in fact the drill might pass through the same shell near the surface and again several hundred or thousand feet below.

The fact that this and other saline nuclei are of concretionary growth and not portions of a widespread bed that has been crumpled up and somehow mysteriously disappeared everywhere except at critical points is, from the oil operator's standpoint, worthy of the most serious consideration. For the upper half of a concretionary mass might be a dome with ideal structure for the concentration of hydrocarbons, whereas the lower portion might show that structure inverted, a most hopeless prospect for oil or gas. To determine the approximate radius of a salt mass, and hence the depths to which wells outside of the mass may be sunk and still meet with upturned and not downturned edges of sedimentary, pervious, oil-bearing strata, an expensive hole centrally located might perhaps be justifiable, but it should be understood that the sinking of a deep well through a great salt nucleus must necessarily be without direct financial results.

Oil and gas.—In 1899 Veatch[a] wrote as follows regarding two shallow wells across the canal to the east of the first shaft: "In hole No. 10 gas was struck at a depth of 120 feet in sufficient quantities to throw sand all over the derrick. It is now bubbling out of the hole, where it can easily be collected and ignited. A small amount of gas and oil was struck in hole No. 4."

In the state report of 1907[b] was given a description of the specimens saved at various depths from well I, with remarks on samples made by the driller in charge. Oil was noted at depths of 1,160, 1,212, 1,220, and 1,365 feet and the "best oil showing yet" at 1,370 feet. Knapp's notes give the depth of the "amber oil" as 1,840 feet. It is said to be of paraffin base and to become nearly solid paraffin on one day's exposure to the sun.[c] The same is true of the oil coming in small quantities from the Knapp well No. 1.

Well H, across the canal, northeast from the shaft, is said to show an oil sand at 420 feet, the lowest sand mentioned in the log given on page 83 of the state report for 1907.

In well D, 425 feet east of the shaft or 200 feet west of well H, a dark oil occurs at 384 feet.

Conclusions.—That the oil possibilities of Belle Isle are exhausted should not for a moment be supposed. When the origin of the saline mass is taken into consideration, inasmuch as its known depth is great and oil and gas manifestations are abundant, there is every reason to believe that just outside of the compressed and slickensided upturned edges of the sedimentary strata in contact with the uplifting saline mass there are pools of oil and gas not yet tapped because deep drilling has been done only into the salt mass itself or too far away, into undisturbed strata. A well put down 100 or 200 feet east of well D or north of well I to a depth of 1,800 feet would more nearly give the island a fair oil test.

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[a] Rept. Louisiana Geol. Survey for 1899, p. 224.

[b] Idem, 1907, pp. 80-81.

[c] Ueberloddhe, Oil Inv. Jour., December 20, 1908.

GOLDONNA.

Location.—The little hamlet of Goldonna is on the Louisiana and Arkansas Railway, in the western part of Winn Parish, about a mile west of the center of the extensive stretch of salt springs long known as Drake's salt works or saline. Veatch's map of this saline is reproduced here as figure 4.

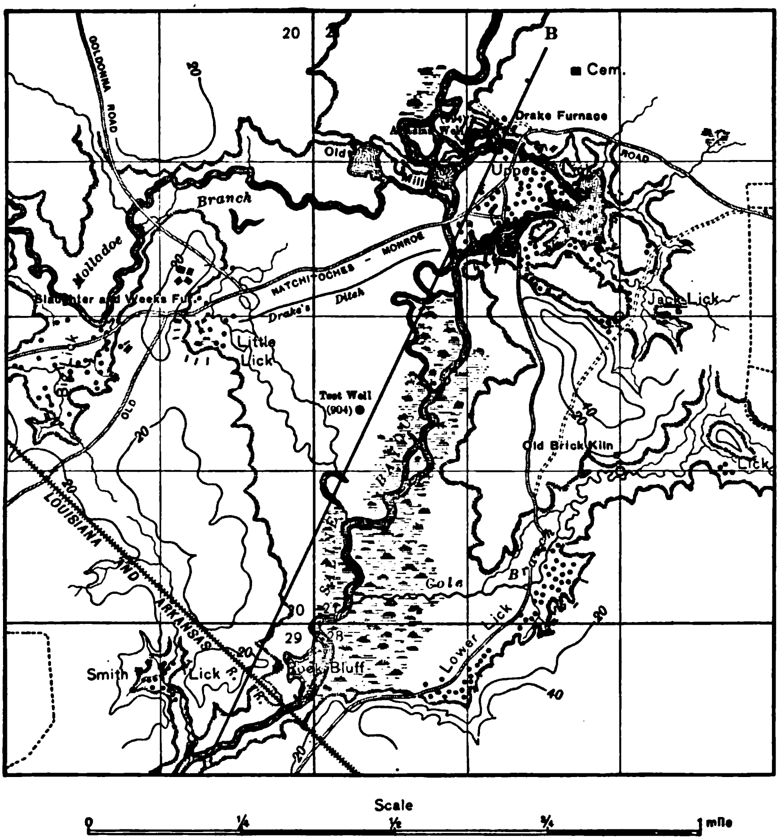

FIGURE 4.—Map of Drake's salt works, Winn and Natchitoches parishes (1899), showing characteristic symmetrical circular arrangement of shallow brine wells around the truncated domes of northern Louisiana.

History and geology.—The "test well" in the center of the area mapped was sunk by Savage Brothers and Morrical in 1905–6, evidently on the supposition that the nearer they came to puncturing the crown of the dome the more sure they would be to strike quantities of oil or gas.

The writer's interpretation of these domes, as shown in figure 5, which indicates the salt-water seeps circularly or marginally arranged, would lead to the expectation of finding whatever pockets of oil and gas there may be about the dome in the flanking strata, whose porous members have been pinched out by the upward movement of the salt mass. Indeed, a letter from the postmaster at this locality says: "They have put down another well one-half mile north of the first and have found quite a lot of gas and some oil, but no salt."

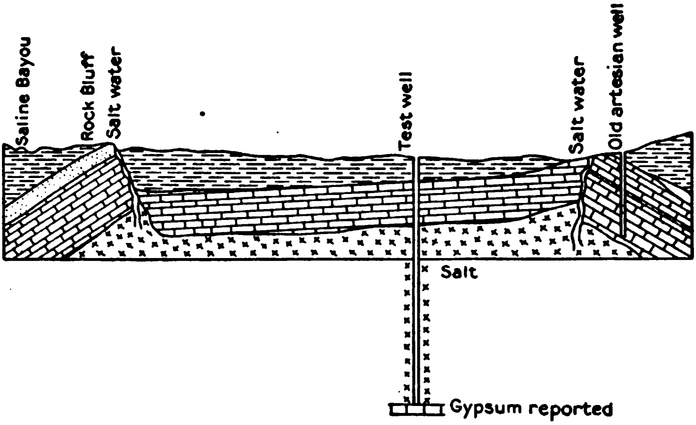

FIGURE 5.—Hypothetical cross section of Drake's saline.

According to the driller in charge of the well March 24, 1906, the time of the writer's visit, the log of the completed well may be stated in outline thus:

Log of well at Goldonna.[a]

	Feet.
Soil, muck, pebbles, logs	0- 303
Limestone (like marble at Winnfield)	303- 910
Salt	910-2,320
Gypsum bed at bottom	2,342

Here is evidently another Anse la Butte in general structure, except that the salt mass has not been truncated by fresh, near-surface waters, but by the resistant rock strata above.[b]

JENNINGS OIL FIELD.

LOCATION.

The Jennings oil field is located in Acadia Parish, southern Louisiana, near the center of T. 9 S., R. 2 W. It is reached most conveniently by private conveyance from the village of Jennings, a station on the Southern Pacific Railroad, about 188 miles west of New Orleans. The oil field is about 6 miles northeast of Jennings. The stations Egan on the branch road and Mermentau on the main line are slightly nearer the field in a direct line than Jennings, but communication with the field from these points is roundabout and extremely unsatisfactory.

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[a] Rept. Louisiana Geol. Survey for 1907, p. 52.

[b] For discussion of the different types of salt cones, together with their manner of growth, see Econ. Geology, February, 1909, pp. 21-30.

TOPOGRAPHY.

To one accustomed to rugged topography, the slight undulations shown on the Jennings sheet (Pl. XI, Rept. Louisiana Geol. Survey for 1907) seem insignificant in the extreme. The country seems monotonously flat. Many of the 5-foot contour lines are long distances apart. Near the bayous, however, as might well be expected, there are some slight declivities; but there are no bluffs; no rock exposures. In the bayous the Gulf tides are felt, and during dry seasons the level of these streams is practically that of the Gulf. The area shown on the map just referred to is one that in late Quaternary time was occupied by the Gulf waters; in other words, it is but a portion of the Gulf floor that has been raised a few feet above tide and is now slightly dissected by sluggish meandering streams.

From the above statements it may be safely concluded that the region about the Jennings field shows no topographic features that could be properly referred to differential orogenic movements. Southern Louisiana as a whole has in recent geologic time appeared above the Gulf level either by a slight upward movement of the continental area or by a slight withdrawal of the sea.

But the eye experienced in discerning topographic forms quickly catches the low hill or mound flanking the oil field on the east. (See Pl. VII.) This hill rises to an elevation of 32 feet above the Gulf, though comparatively close to Bayou des Cannes and hence naturally more subjected to erosive agencies than, for example, Mamou Prairie, 1 to 3 miles to the northwest. Like the mounds at Anse la Butte and at Spindletop, this is the highest land for miles around. It seems clearly due to dome structure of extremely small lateral extent.

West of the mound, near the central portion of the old productive area, there was formerly a swampy tract. Recent developments have more or less obscured the topographic features of this tract, but traces of its depressed character are still discernible. Small streams coming in from the northeast and the northwest traverse this lowland and after uniting pass the southern limits of the proved field with comparatively high banks on either side (Pl. VI). In other words, contour lines that are near together in this outlet channel tend to spread out and inclose a great area in the swampy northern reaches of these streams. Here too, then, as at Anse la Butte, there are evidences of local uplifting across the main stream channel, uplifting that has gone on at the same time as the degrading of the channel.

The oldest inhabitants maintain that within their earliest recollections the swampy character of the lowlands to the west of the mound was far more pronounced than in late years, and that good-sized trees were common there. The salt water, oil, and noxious gases have swept away the last traces of the primeval woodland. Whether this desiccation in comparatively recent years is due to a general increasing aridity of climate in this region, or to the lowering of the stream beds so that the moist lands have become drained, can not at present be determined.

The Jennings oil field is accordingly located close to the scenes of extremely local orographic phenomena, which have taken place in comparatively recent times in a generally uninteresting, monotonous coastal plain.

DISCOVERY OF THE FIELD.

A spring not many yards north of the first well in the field, "Jennings Oil Company No. 1" (see map, fig. 6), had been known even to the earliest settlers as being somewhat remarkable in that it was apparently located on high ground and the water was always agitated by escaping gas. As the locality showed a mound, a depression, and gas emanations, in accordance with the signs at Beaumont (Spindletop), it is little wonder that immediately upon the discovery of oil at the latter locality in January, 1901, the "Mamou" region should be looked upon with favor. The Jennings Oil Company procured the services of the Heywood Brothers, successful operators in the Spindletop field, to put down a test well. In August, 1901, it had reached "pay sand" and was down 1,822 feet.[a] It gushed oil and sand

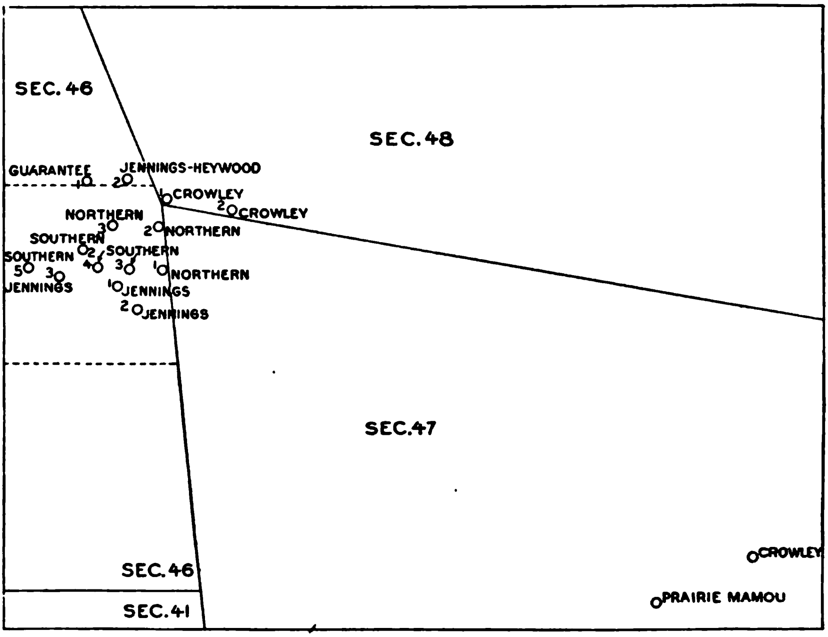

FIGURE 6.—Map of the Jennings oil field, January-February, 1903.

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[a] Oil Inv. Jour., June 21, 1902, p. 7; October 15, 1904, p. 5. Fenneman (Bull. U. S. Geol. Survey No. 282, 1906, p. 95) applies practically the same data to a well of the "Southern Oil Company."

spasmodically for seven hours and then clogged up. Though this well was not successful financially, it proved the presence of oil and gas in considerable quantities in the Mamou region.

HISTORY OF DEVELOPMENT.

Southern No. 1 was soon started in the woods 2 miles south of the pioneer Jennings well, but though it attained, according to reports of the time, a depth of 2,600 feet it was not a success. The materials brought out from near the bottom of the well showed no characteristic extinct species of shells and had a decidedly fluviatile appearance. Southern No. 2, close to the pioneer Jennings, was the next to come in. Oil was said to be coming from a depth of approximately 1,785 feet, though some shells shown to the writer were reported to have come from about 1,800 feet. Drillers accustomed to obtaining oil from the porous limestone at Spindletop at first did not know how to manage the fine incoherent sand at Jennings. Southern No. 2 had no strainer, hence it is no wonder that it did not gush after the Spindletop fashion. However, as remarked by the Oil Investors' Journal, "The flow of oil was sufficient to further convince the Jennings people and the Heywoods that they had found another Spindletop."

The relation of the "hill" or mound in the Jennings field to the pool of oil was quickly found to be very different from the analogous relation in the Spindletop field. In March, 1902, the Mamou well, on the "hill," and the Crowley well, just to the east, were practically abandoned. (See fig. 6.) The former was then reported to have attained a depth of 2,400 feet, the latter about 2,200. The Mamou well may have attained a depth of 2,200 feet, but the Crowley well probably did not exceed 1,200 feet. They were both unsuccessful so far as oil is concerned, but the Crowley well showed among other fossils *Rangia johnsoni*, a typical upper Miocene species. The importance of this discovery in the study of the southern oil fields was noted in the Louisiana Geological Survey report for 1902.

Before midsummer of 1902 Jennings No. 3, Pelican No. 1, and Home Oil Company No. 1 had been drilled along the road from the oil field to Jennings, along a "supposed line of the anticline," [a] without remunerative results. The field was therefore regarded as extending for but a moderate distance about the pioneer Jennings and Southern No. 2, west of the "hill," near the central part of T. 9 S., R. 2 W. In other words, the Jennings field seemed to be located in a hollow, whereas Spindletop was on a hill. In this "proved field" Southern Nos. 3 and 4 were fairly successful as gushers, though the former had two strings of pipe within the 6-inch casing and the latter was but a 4-inch well. Jennings No. 2, brought in by the Heywood

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[a] Hayes and Kennedy, op. cit., p. 128.

Brothers June 28, 1902, was perhaps the first really satisfactory well in the field. Its 6-inch casing was carried down 1,800 feet, and great pains were taken to perfect and lower the strainer or "liner" to the oil sand.

Profiting by the mistakes of the Spindletop and Sour Lake fields, those interested in the Jennings field had built a well-equipped 4-inch pipe line to Jennings before these successful gushers had been brought in. In midsummer, 1902, oil was being loaded at Jennings into Southern Pacific tank cars. The Heywood Transportation Company operated 25 barges and 6 steamers and tugs on Mermentau River and its tributaries, and rice growers for miles around took away hundreds of barrels of oil daily to burn in their irrigating plants. The prices ranged from 30 to 40 cents a barrel, according to the quantity sold.

In 1903 the proved field was extended at least 1,000 feet westward by the Superior Company, and the Crowley company was rapidly extending its bounds to the northeast. (See Pl. VI.) A 6-inch pipe line from the field to Mermentau station, on the Southern Pacific Railroad, was completed and equipped with pumping stations, loading racks, and steel tanks, but owing to high pipe-line rates the Crowley company found it necessary to construct a 4-inch line to the Eunice branch of the Southern Pacific Railroad. This was completed before the middle of 1904. In the meantime (January 14, 1904) the famous Chicago-Jennings well No. 2 had been brought in, giving the field over 2,000 barrels of new production and extending its bounds several hundred feet to the south. The remarkable success of this well was attributed by some to the fact that the superior Getty "liner" was used in it. The fair success of the Jenkie well, still farther south, led development rapidly in that direction. There were 33 producing wells in this field February 5, 1904.

Production from the deep (1,900 feet) sands in the southeastern part of the field was begun by the Morse Company in July, 1904. Producers (Latreille 40-acre tract) No. 1 was a 4,000-barrel addition to the field, and extended its limits 500 feet to the southeast. Bass & Benckenstein's No. 1, though scarcely extending the limits of the Jennings field, set a new pace for single-well production in the field, furnishing about one-half the 28,000 barrels produced daily by the whole field in October, 1904. In the fall of 1904 the Heywood Oil Company brought in its famous No. 1, which furnished a new production of 10,000 barrels. Early in 1905 Bass & Benckenstein completed a 6-inch pipe line to Egan, on the Eunice branch of the Southern Pacific Railroad, and before the middle of the year had a 4-inch extension from Egan to Atchafalaya River and were shipping thence by barges up and down the Mississippi. This line is said to be 54 miles long. In the fall of 1905 Bass & Benckenstein, with

Mr. Carns, formed the Evangeline Oil Company of New Jersey, and thereafter all their holdings were known by that designation.

The season of 1905 was discouraging in many ways. Most of the wells had become "pumpers" and in many wells large quantities of salt water were brought to the surface with the oil. Although somewhat more oil was produced in 1905 than in the previous year, prices were such that the total value of the production was but two-thirds what it had been when the large gushers were most active.

In 1906, however, the Heywood Oil Company brought in its No. 1 on the Crowley lease, which proved to be a spouter of first quality, yielding 8,000 barrels daily without salt water. This added 500 feet to the proved territory on the northeast. The Jennings-Heywood Oil Syndicate's $100,000 air plant was installed in the autumn of 1906. In spite of decreased production from individual wells and the large amount of salt water appearing in many, prices were somewhat more encouraging and this year marks the maximum production of the Jennings field—a trifle over 9,000,000 barrels. The year was also marked by the completion of the Texas Company's 6-inch pipe line to Lake Charles, on the Kansas City Southern Railway. Oil was turned into this line on March 13, and for the first time in the history of the field oil could be shipped on a railroad other than the Southern Pacific.

Though the Crowley Oil and Mineral Company had extended the field perhaps 200 feet to the north by bringing in its No. 21, a shallow gusher of black oil, the failure of its deep well 3,000 feet to the north, toward the residence of Mr. Clement, early in 1907, discouraged prospects in that direction. About the same time the Teche Development Company again proved the comparative barrenness of the "hill" to the east of the proved field. The appearance of the field at this time is shown in Plate VII. Scott Heywood proved that the old part of the field was not entirely exhausted by bringing in two fair wells within its limits; but the important development was the Producers Oil Company's No. 13, in the Latreille 40-acre tract, yielding 1,300 barrels daily. This well extended the field one-fourth mile to the southeast and, although not to be compared with some of the 1904 gushers for quantity of oil produced, must be regarded as a record well for value of production. With oil at $1 a barrel it netted its owner $42,000 the first two weeks. A limit to the extension in a southeasterly direction was established by the completion of the Duson & Lyons well, south of the Producers, in salt water, and the lack of production in the Guffey well, on the King tract southeast of the Producers, though it went down 2,000 feet. The Franklin well, three-fourths of a mile east of the field, drilled in 1906, was finally abandoned. Though prices were on an average much more satisfactory in 1907 than they had been in 1906, the increase of salt water and the necessity of finding storage for it on account of the complaints of the rice growers in the surrounding country caused the cost of production to advance rapidly.

Early in 1908 considerable activity was directed to that portion of the field lying a fourth of a mile west of the old developments, in and about the Eunice-Crowley lease. This was brought about by the satisfactory results of the Noble Company's well No. 1. In general, the production of the wells was decreasing, salt water was increasing, salt-water storage was again called for during the rice irrigating season, prices were depressed, and, except perhaps in the Producers 40-acre Latreille lease, the end of production seemed fast approaching. Perhaps the most noteworthy event of the year was the withdrawal of the Heywood Brothers from active interest in the operations of the field. They sold out to the Gulf Refining Company for $300,000 cash and certain royalties. The purchasers at once took active steps to develop their holdings, but apparently have so far met with no marked financial success.

STRATIGRAPHY OF THE FIELD.

In the state report of 1902 it was inferred that there were probably considerable irregularities in the stratigraphy of the Jennings oil field, and *Rangia johnsoni*[a] was cited as indicating a Miocene horizon for the oil-bearing sands. Yet at that time there were but few wells in this field and no facts regarding the dip were known. During the field work in mapping the Jennings area, L. Reinecke was delegated to collect oil-well data for the present report. His work was admirably done, but the poor state of preservation of small, soft fossil remains in rotary drillings renders paleontologic investigations extremely difficult. However, the fossils have been placed in the competent hands of Miss C. J. Maury and her observations and conclusions are herewith given:

> In the Jennings oil field fossils were collected by Mr. Reinecke from 31 wells. Twenty-five genera were represented, but most of the fossils were so fragmentary and worn that only 13 species could be determined. Some of these are found in the Miocene; others range from the Miocene, Pliocene, or post-Pliocene to the Recent. The species occurring most commonly in the wells are *Rangia johnsoni* and *Rangia cuneata*. [See figs. 7 and 8.]
>
> It is generally thought that *Rangia cuneata* does not descend below the Pliocene and that *Rangia johnsoni* is upper Miocene, but the two species occur together at various levels in the Jennings-Heywood Oil Syndicate's wells Nos. 27 and 29 and in the Teche No. 1, where they are associated to depths exceeding 2,100 feet. Mr. Aldrich also reports *Rangia cuneata* from the Miocene, although he regards *R. johnsoni* as Pliocene. This extension of the time range of *R. cuneata* to the Miocene largely destroyed its value as a guide in determining the stratigraphy of the oil field.

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[a] Rept. Louisiana Geol. Survey for 1902, p. 269. Late Miocene or early Pliocene, according to Doctor Dall (January 10, 1909).

The horizontal and vertical distribution of *Rangia johnsoni* in these wells has been traced. The highest levels at which the species occurred in all the wells in which it was found were marked on a map of the field. Two interesting facts were thus brought to light—first, that the *Rangia johnsoni* strata are penetrated only by wells in the eastern part of the field; second, that the levels at which the strata were reached lie more or less radially and show a progressive deepening from certain centers. [See heavy contours, Pl. VII.]

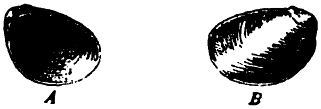

FIGURE 7.—*Rangia johnsoni.* *A*, Interior, right valve; *B*, exterior, left valve.

Thus, taking as the first center the Jennings-Heywood Syndicate's No. 29, we find at this point the *Rangia johnsoni* strata at their highest level in the whole field—that is, at 1,040 to 1,120 feet below the surface [not below sea level, shown in Pl. VII]. At the Syndicate's well No. 24 the level is at 1,125 to 1,185 feet. Farther north, at the Syndicate and Caffery & Martel's well No. 25, it deepens to 1,500 feet; and at the Heywood-Crowley No. 9, in the same arc, we find it at 1,503 to 1,519 feet. The horizon deepens to the southeast, at the Syndicate's well No. 27, to 1,970 to 1,980 feet. [Compare Pl. VII.]

The second center is at the Teche No. 1 well, where the *Rangia johnsoni* strata reach the third highest level in the field—1,322 to 1,363 feet. This level deepens to the northwest, at the Syndicate's well No. 28, to 1,710 feet, and on the west, in the Benckenstein, Caffery & Martel No. 3, to 1,990 feet, while far to the east, in the Franklin No. 1 well, the level sinks to 2,183 to 2,204 feet.[a]

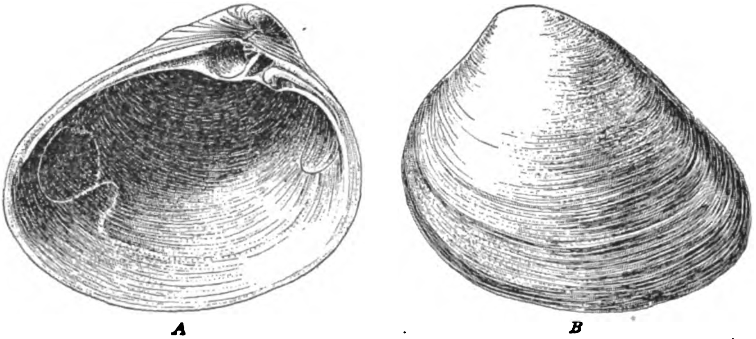

FIGURE 8.—*Rangia cuneata*, left valve. *A*, Interior; *B*, exterior.

The presence of two mounds in the *Rangia johnsoni* strata is thus indicated. These are oriented nearly at right angles to one another. [See Pl. VII.]

In addition to the two species of *Rangia* the only shell occurring with much frequency in the Jennings wells is *Mulinia quadricentennialis*. This shell was found and described by Professor Harris from the upper Miocene of the Galveston artesian well at a depth of 2,236 to 2,871 feet. It is fairly common in the Jennings wells, but usually not in those in which *Rangia johnsoni* is found. In the exceptional cases it was once above and once below *Rangia johnsoni*. It occurs at levels varying from 1,680 to 2,012 feet. Strata characterized by *Mulinia quadricentennialis* outskirt the *Rangia johnsoni* beds and extend westward to Zeigler No. 15 (Valée), northward to Crowley No. 24, and southward to Producers Nos. 3 and 4.

A curious new species which we have named *Rangia mamouensis* was found in the Heywood (Crowley lease) No. 8 well at 2,050 and 2,115 to 2,131 feet, in the same company's No. 9 at 1,670 feet, and in Producers No. 8 (Latreille) at 1,990 to 2,012 feet.

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[a] See Bull. Louisiana Geol. Survey No. 6, 1907. Well is outside of the area shown on the map.

In tracing the distribution of the remaining species the striking fact was observed that not a single characteristically Miocene species has been obtained from the wells in the western part of the field with the exception of a *Spisula* which is doubtfully referred to as *S. quadricentennialis* Harris, and this shell was found far to the west, in the Duson & Lyons No. 1 well, at 1,860 to 1,910 feet. Except for this doubtful shell, from all the wells east of the Zeigler No. 15 (Valée) we have Miocene species and from all the wells west of the Zeigler No. 15 we have only species which are still in existence in the Recent fauna, although fossils were obtained from some of these wells to a depth of 1,800 to 1,900 feet. A similar absence of Miocene species was noted south of Producers wells Nos. 3 and 4.

In conclusion, the writer believes that there is a Miocene dome underlying the eastern part of the Jennings oil field; that the center of this dome consists of strata characterized by *Rangia johnsoni;* that these strata form two mounds extending northeast-southwest and northwest-southeast, approaching each other at the west; that the *Rangia johnsoni* strata are surrounded on the north, south, and west by other upper Miocene strata, characterized by *Mulinia quadricentennialis*, which form the boundary of the Miocene dome; that the parts of the field lying to the west and south of the dome, where no strictly Miocene species have been found to a depth of 1,800 to 1,900 feet, are post-Pliocene; and that the break between the Miocene dome and the post-Pliocene areas is marked by two faults nearly at right angles to each other, the chief fault running northeast and southwest just west of the Zeigler No. 15, and the minor fault running northwest and southeast south of Producers wells Nos. 3 and 4. [See Pl. VII for location of wells and domes.]

It is quite probable that the general surface of the Miocene *Rangia johnsoni* zone is, in this vicinity, but little more than 2,000 feet below the present surface of the ground, for half a mile north of the field, in Crowley No. 25, this fauna is found abundantly from 1,960 feet to more than 2,600 feet. Still this may be the locus of a slight uplift, or the Miocene character of the fauna may be imparted to Quaternary deposits by the inwash from near-by Miocene uplifts.

Along with these data, mainly paleontologic, may well now be considered certain others that have been often commented upon but rarely explained; all are so related that the main features of the geologic history of the field can no longer be regarded as obscure. It is well known that the area from the Heywood well No. 1 on the Crowley lease southwestward to a point south of the Chicago-Jennings wells was the great gusher area of the field. In the northeastern part of this tract indurated masses of pyritiferous sands and clays occur and vary greatly both as to thickness and lateral extent.

It is also well known that the oil-bearing sands range in depth from 100 to 2,400 feet, especially in the western part of the field, though the main producers are from 1,800 to 2,100 feet deep. The shallowest bed of all has been developed farthest away from the gusher territory in the extreme southwestern part of the field.

The unusually large amount of sand and gravel encountered throughout the field in sinking wells has been noted [a] but not explained.

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[a] Bull. U. S. Geol. Survey No. 282, 1906, p. 98.

The commingling of *Rangia cuneata*, supposed generally to be a Quaternary form, with *R. johnsoni*, a late Miocene or early Pliocene form, has been looked upon as strange and as indicating that *R. cuneata* must necessarily be regarded as beginning in the Miocene, in this region at least. But there is another explanation, as will appear below.

The absence of a porous limestone containing oil, like that at Spindletop, and the depressed surface in the center of the field, in marked contrast to many other saline-dome areas, are other features that have been considered unusual.

All these facts receive a ready explanation if it is assumed that the field had a saline-dome origin. In early Quaternary time a more or less quadrangular block was being pushed up unequally, the west corner the most rapidly. The movement gave rise to a fault along the northwest and southwest sides of the uplift and through the fault fissure hydrocarbons from below escaped into the edges of the newly-formed Quaternary beds on the west and the Miocene beds on the east. The Miocene area was rising rapidly and was perhaps being eroded, furnishing its Miocene fossils with other material for Quaternary deposition. This may account for the seemingly strange commingling and alternation of fossils belonging to such distinct periods. The eastern or Miocene area was pushed up in places at least 1,000 feet above beds of similar age in the western part of the field.

At the east the Quaternary beds are but 1,000 feet thick, but in most parts of the field they exceed 2,000 feet. In later Quaternary time the unequal uplifting was less intense and the Miocene beds were carried down, with the surrounding Quaternary beds, beneath 1,000 feet of more recent deposits. Still, the uplifting forces have continued during late Quaternary time and, as remarked before, have doubtless been somewhat active up to the present day. Their tendency to keep this area above or about at sea level while surrounding regions were rapidly sinking furnishes a ready explanation of the coarseness of the deposits here, proved by logs of the Jennings wells as compared with records of wells but a few miles away. Slightly elevated or exposed points, like Point au Fer, are to-day being surrounded by very much coarser material than is being deposited in Atchafalaya Bay, only a few miles distant. Let Point au Fer be held from sinking quite as rapidly as the surrounding areas by the growth of a saline dome beneath, and in course of time a well sunk near the location of the point would pass through surprisingly coarser materials than would be found in wells sunk a few miles away in any direction. The depression in the west-central part of the field is readily accounted for by the gradual settling of 2,000 feet of Quaternary deposits in juxtaposition to beds composed of 1,000 feet of

Quaternary and 1,000 feet of older Miocene and hence more compact deposits.

Along with the hydrocarbons escaping upward through the main fault fissure already defined would naturally go (*a*) various saline solutions causing local indurations (rock), (*b*) an ever-ready near-by quantity of salt water seeking by most unexpected and circuitous routes to occupy all space possible, (*c*) here and there a supply of hot water, and, finally and most naturally, (*d*) gas escaping even at the surface.

The minor details of the occurrence of oil and gas, pyrite, and indurated calcareous masses, salt and hot waters, as well as many other valuable statistics, have already been published by the United States Geological Survey in Bulletin 282 and hence need not be repeated here. The general scheme or plan of the field—the stratigraphy—however, has never before been explained.

CONCLUSIONS.

That the oil in the Jennings field has come up through a crevice or fault fissure and spread laterally into Quaternary and Miocene beds there can be no doubt. Though the best producing "sands" in the central portion of the field lie about 1,800 to 2,100 feet beneath the surface, others to the west, some even but 100 feet below the surface, have been filled by seepages from the central fissure. To the east the Miocene beds descend rapidly and little seepage could take place in that direction.

So far as easily attainable new production is concerned the Jennings field is not promising.

The angular area uplifted in the eastern part of the field, seemingly bounded on two sides by fault lines, suggests that the deep-lying saline dome is probably capped by a layer of considerable rigidity, somewhat after the manner shown in figure 5. This may be a porous limestone similar in origin to that which furnished the gusher production at Spindletop. An experimental well sunk to prove the presence of such a rock within attainable depths should naturally be begun in the east-central portion of the field, where uplifting has been most pronounced.

WELLS IN THE JENNINGS FIELD.

In the following list of wells in the Jennings field to December. 1908, the dates given have been obtained almost exclusively from the reports appearing during the past eight years in the Oil Investors' Journal. The well sections were obtained mainly by Mr. Reinecke, and those which are merely copies of records are duly accredited to the driller in charge. The fossils have been identified by Miss C. J. Maury. The location of wells has been determined by the

Louisiana Geological Survey for various periods in the history of the field, as shown on the maps (fig. 6, Pls. VI, VII, and VIII). Minor inconsistencies undoubtedly exist in the data represented on the various maps, made several years apart under widely varying circumstances. Some of the locations are not as accurate as could be desired. Wells are drilled and are abandoned sometimes without leaving definite marks for location. Some wells have been missed entirely. Under the circumstances, however, it has been impossible to do more.

In the subjoined list the name given after the section number is that of the subdivision or tract in which the well is located. The map numbers are those used on Plate VIII.

Annotated list of wells in the Jennings field.

American Oil Company, No. 1; sec. 45; Schultz subdivison; drilled, summer, 1903; map No. 436.

Arlington Oil Company, No. 1; sec. 47; Moonshine 1 acre; drilled, December, 1907; salt water; map No. 268.

Arlington Oil Company, No. 2; sec. 47; Moonshine 1 acre; drilled, February, 1908; yield 300 barrels in March, 1908; map No. 247.

Arlington Oil Company, No. 3; reported, 1908, under name of Great Southern, No. 1; location not determined.

Attakapas Oil Company, No. 1; sec. 47; Moonshine subdivision; drilling, fall, 1904; stopped by injunction; map No. 272.

Attakapas Oil Company, No. 2; sec. 47; Moonshine 1 acre; drilled, spring, 1905; map No. 246.

Bass (T. H.) & Co., No. 1; sec. 42; Mattison subdivision; drilled early in 1908; produced daily 400 barrels of oil, then oil with salt water; producing in November, 1908; map No. 28.

Bass No. 1, sec. 47; Bass subdivision; not producing in 1908; map No. 234.

Bass & Guffey, No. 1; sec. 47; Guffey Petroleum Company; drilled, spring, 1903; yield, 5,000 barrels in June, 1903; deepened, 1905; yield, 1,000 barrels in March, 1905; formerly known as Morse No. 1; map No. 357.

Bass No. 2; sec. 47; Guffey Petroleum Company; drilled, summer, 1903; produced, 1903–4; deepened and produced, 1905; formerly known as Morse No. 2; map No. 350.

Bass No. 2; sec. 47; Bass; made 1,500 barrels of oil and went to salt water, January, 1907; map No. 235.

Bass No. 2; sec. 42; Mattison lease; drilled, spring, 1908; 250 barrels in March, 1908; producing, November, 1908; map No. 38.

Bass Nos. 3, 4, 5. See Morse Nos. 3, 4, 5.

Bass No. 6; sec. 47; Martin; drilled, spring, 1904; 6,400 barrels in June, 1904; 200 in April, 1905; 125 in May, 1905; deepened, produced, and sanded up, fall of 1905; map No. 386.

Bass No. 7; sec. 47; drilled, spring, 1904; first deep well on Arnaudet tract; flowed from July, 1904, to close of 1905; producing, 1908; map No. 368.

Bass No. 8; sec. 47; Morse; drilled, summer, 1904; 7,500 barrels in November, 1904; 400 in May, 1905; producing, fall of 1906; map No. 364.

Bass No. 9; sec. 47; Morse; drilled, fall, 1904; 500 barrels in April, 1905; not producing, June, 1906; abandoned 1907; map No. 363.

Bass No. 10; sec. 47; Guffey Petroleum Company; drilled early in 1905; produced in 1905; abandoned, 1907; map No. 351.

Bass No. 11 (Ladies No. 1); sec. 47, Home; drilled, spring, 1905; salt water; map No. 366.

Bass No. 12; sec. 47; Home; drilled, spring, 1905; a pumper; map No. 355.

Bass No. 13; sec. 47; Home; drilled, fall, 1905; map No. 415.

Bass No. 14; sec. 47; Morse; drilled, fall, 1905; produced some oil and salt water; deepened, summer, 1906; map No. 369.

Bass No. 17; sec. 47; Guffey Petroleum Company; drilled, spring, 1906; salt water; deepened, August, 1906; map No. 358.

Bass No. 16. See Gulf Refining Company No. 16.

Bass No. 18; sec. 47; Guffey Petroleum Company; drilled before 1907; data lacking; map No. 360.

Bass No. 18; sec. 47; Guffey Petroleum Company; drilled, summer, 1906; a 2,000-barrel well; abandoned, 1908; map No. 128.

Bass No. 19; sec. 47; Guffey Petroleum Company; drilled, winter, 1906–7; 75 barrels in February, 1907; abandoned, 1908; map No. 356.

Benckenstein, Caffrey & Martel No. 1; sec. 47; Benckenstein; drilled, summer, 1906; 1,000 barrels on air, July, 1906; abandoned, 1908; map No. 230.

Benckenstein, Caffrey & Martel No. 2; sec. 47; Benckenstein; small pumper, 1906; map No. 231.

Benckenstein, Caffrey & Martel No. 3; sec. 47; Benckenstein; drilled, fall, 1906; dry hole, deepened and twisted off twice; map No. 232.

Benckenstein and Sharp. See Sharp and Benckenstein.

Bienville No. 1; sec. 47; Home; drilled, summer, 1903; produced, 1903–4; map No. 431.

Bienville No. 2; sec. 47; Home; drilled, summer, 1903; produced, 1904; deepened, 1904; map No. 361.

Caffrey & Martel No. 1; sec. 47; Moonshine 1 acre; map No. 245.

Carencro No. 1; sec. 45; Conklin; drilled, spring, 1908; salt water; deepened, May; pumping, November, 1908; map No. 8.

Carencro No. 2; sec. 75; Conklin; producing, 1908; map No. 441.

Carencro No. 3; sec. 45; Conklin; drilled, fall, 1908; salt water reported, October, 1908; map No. 7.

Charleston No. 1; sec. 41; Syndicate Fee Simple; drilled, spring, 1904; too deep; salt water; map No. 409.

Chicago-Jennings No. 1; 1½ miles northwest of oil field, Garrould tract; depth 2,230 feet; dry; see section, Bull. U. S. Geol. Survey No. 282, p. 97.

Chicago-Jennings No. 2; sec. 46; Chicago-Jennings; brought in January 14, 1904; produced 2,500 to 3,000 barrels daily for over a month; pumping, October, 1906; deepened, 1906; map No. 86. *Rangia cuneata* was found at 1,518 feet.

Section of Chicago-Jennings well No. 2.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	43	43	Gumbo and gravel	60	1,470
Sand	175	218	Pyrite and gumbo	40	1,510
Sand and clay	580	798	Shale, gravel, and gumbo	82	1,592
Sand	80	878	Rock	18	1,610
Gravel	41	919	Gumbo and shale, oil traces	74	1,684
Gumbo	175	1,094	Rock, shale, and gumbo, good oil showing	73	1,757
Gumbo and gravel	100	1,194	Shale and pyrite, good oil showing	40	1,797
Gravel and rock	55	1,149	Coarse sand and pyrite, abundance of oil	53	1,850
Gumbo	40	1,289			
Gravel, gumbo, and shale	91	1,380			
Shale and pyrite	30	1,410			

Total depth 1,854 feet; Getty liner.

Chicago-Jennings No. 3; sec. 46; drilled, spring, 1904; producing, fall, 1904; deepened, 1906; abandoned, 1907; map No. 408.

Chicago-Jennings No. 4; sec. 46; Chicago; drilled, spring, 1904; accidentally ruined; map No. 433.

Chicago-Jennings No. 5; sec. 46; Chicago; drilled, summer, 1904; salt water; abandoned, 1905; map No. 74.

Chicago-Jennings No. 6; sec. 46; drilled in 1903 and produced in 1905; deepened to salt water, 1907; map No. 75.

Chicago-Jennings No. 7; sec. 46; Chicago-Jennings; drilled to salt water, summer, 1906; deepened, 1908; produced 500 barrels, November 1908; map No. 432.

Chicago-Jennings No. 8; sec. 46; Chicago-Jennings; drilled, January, 1907; 200 barrels, February, 1907; producing, November, 1908; map No. 85. Fossils, collected by L. Reinecke and identified by C. J. Maury: *Rangia cuneata*, 60–540, 1,239–1,860 feet; *Ostrea*, 1,238–1,378 feet; crinoid stem (Carboniferous drift), 832–875 feet.

Section of Chicago-Jennings well No. 8.

	Thickness.	Depth.
	Feet.	*Feet.*
Yellow and blue clay	63	63
Green sand, becoming coarser below, with few shells	133	196
Gravel, growing coarser below; pebbles coated with pyrites	534	730
Gravel with fine sand and shell fragments; also a few pieces of limestone	102	832
White sand	63	895
Gravel, more or less pyrite coated	70	965
Blue clay with some gravel	45	1,010
Fine white sand with black specks, pyrite, showing oil	69	1,079
Blue sticky clay with a few pyrite-coated pebbles	160	1,239
Blue plastic clay with many shell fragments; below 1,378 feet pyrites and gravel	366	1,605
Pyrite, gravel, shell fragments	78	1,683
Pyrite, shells, and limestone fragments	34	1,717
Finely ground blue limestone with pyrites	30	1,747
Pyrites and shells	18	1,765
Shells and blue lime fragments; shells over 50 per cent of the whole	23	1,788
Crumbling pyrite fragments and shells	42	1,830
Fine greenish sand, shells and pyrite to 1,860 feet	53	1,890

Eight-inch casing set at 1,752 feet; 6-inch casing set at 1,712 feet; screen, 166.5 feet of 4½-inch; packer at 1,679 feet.

Chicago-Jennings No. 9; sec. 46; Chicago; drilled, spring, 1907; 200 barrels, July, 1907; producing, November, 1908; map No. 406.

Chicago-Jennings No. 10; sec. 46; Chicago-Jennings; location, fall, 1908; map No. 87.

Crescent No. 1 (Wood's well); sec. 46, extreme northern edge of field; drilled, fall, 1903; dry, map. No 140.

Crowley Oil and Mineral Company No. —; sec. 48; Crowley; no data; map No. 316.

Crowley Oil and Mineral Company No. —; sec. 48; Crowley; new derrick, fall, 1908; map No. 320.

Crowley Oil and Mineral Company No. 1; sec. 48; Crowley; drilled, fall, 1902, to spring of 1903, 300 barrels, March, 1903; map No. 354.

Section of Crowley Oil and Mineral Company's well No. 1.

[I. B. Grow, driller.]

	Thickness.	Depth.
	Feet.	*Feet.*
Quicksand and gravel	1,050	1,050
Blue shale	150	1,200
Rock	125	1,325
Blue shale	175	1,500
Shell and gravel	25	1,525
Sand showing oil	10	1,535
Blue shale	40	1,575
Sand, little gas	5	1,580
Blue shale, mixed with some shell rock	103	1,683
Blue hard gumbo	12	1,695
Oil sand	15	1,710
Blue shale, with 6 feet of oil sand at 1,740 feet	50	1,760
Oil sand	65	1,825

Screen, 108 feet.

Crowley Oil and Mineral Company No. 2; sec. 48; Crowley; drilled, winter, 1902-3; produced, 1903; map No. 346.

Section of Crowley Oil and Mineral Company's well No. 2.

	Thickness.	Depth.
	Feet.	*Feet.*
Not given	....	598
Sand	362	960
Blue shale	87	1,047
Small gravel	203	1,250
Blue shale	245	1,445
Shale and sand, showing of oil	10	1,505
Blue shale, with 127 feet of hard rock at 1,530 feet	220	1,725
Blue shale, with slight showings of oil; thin streaks of sand	36	1,761
Oil sand	48	1,809

Screen, 85.75 feet wire-wound copper-gauze strainer.

Crowley Oil and Mineral Company No. 3; sec. 46; Crowley; drilled, summer, 1903; 5,000-barrel gusher; producing, 1905; map No. 337.

Section of Crowley Oil and Mineral Company's well No. 3.

[Lake Grow, driller.]

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	60	60
Quicksand and gravel	840	900
Blue shale	43	943
Gravel	207	1,150
Blue shale	210	1,360
Gravel	50	1,410
Blue shale	20	1,430
Gravel	12	1,442
Blue shale	98	1,540
Shell rock, gravel, and fine sand	20	1,560
Shell and gumbo	32	1,592
Fine white quartz sand and a few flinty pebbles	26	1,618
Coarse oil sand, mixed with gravel and dry asphalt	69	1,687
Blue shale	73	1,760
Oil sand, very hard	40	1,800
Shell and blue shale	10	1,810

Screen, 43 feet of 9-inch, from 1,810 feet up; 100 feet of 7-inch, from 1,647 feet up.

Crowley Oil and Mineral Company No. 4; sec. 48; Crowley; produced, 1903–4; abandoned, 1907; map No. 416. A few fossils were collected from 1,663 to 1,670 feet: *Rangia cuneata*, *Natica*, *Cylichnella bidentata*, and *Arca ponderosa?*

Crowley Oil and Mineral Company No. 5; sec. 48; Crowley; drilled, summer, 1903; salt water; deepened and found good oil, 1904; 150 barrels daily, 1905; abandoned, 1908; map No. 412.

Section of Crowley Oil and Mineral Company's well No. 5.

[Lake Grow, driller.]

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	60	60
Quicksand and gravel	750	810
Blue shale	90	900
Gravel and shell	160	1,060
Blue shale	120	1,180
Gravel and rock	20	1,200
Blue shale	75	1,275
Gravel	25	1,300
Blue shale	100	1,400
Rock, hard gumbo, and shell	100	1,500
Rock	1	1,501
Blue shale	79	1,580
Hard sand; no oil	40	1,620
Gumbo	30	1,650
Hard, fine white sand; no oil	20	1,670
Sand, with pyrite, and good oil showing	30	1,710
Hard sand	24	1,734
Gumbo	6	1,740
Shell rock, top of oil sand	......	1,740
Almost solid oil sand; salt water in this stratum above the oil	80	1,820

Screen, 82 feet.

Crowley Oil and Mineral Company No. 6; sec. 48; Crowley; drilled, 1903; produced, 1903–1905; abandoned, 1907; map No. 417.

Crowley Oil and Mineral Company No. 7; sec. 48; Crowley; drilled, spring, 1903; produced, 1903–1905; map No. 352.

Crowley Oil and Mineral Company No. 7; new outfit close to No. 7; producing, 1908; map No. 352.

Crowley Oil and Mineral Company No. 8; sec. 48; Crowley; drilled in latter part of 1903; map No. 353.

Crowley Oil and Mineral Company No. 9; sec. 48; Crowley; drilled, fall, 1903; produced, 1904; abandoned, 1907; map No. 425.

Crowley Oil and Mineral Company No. 10; sec. 48; Crowley; drilled, fall, 1903; produced, 1904–5; abandoned, 1907; map No. 338.

Section of Crowley Oil and Mineral Company's well No. 10.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	60	60
Quicksand and gumbo	1,100	1,160
Blue shale	490	1,650
Oil sand, mixed with streaks of gumbo; screen set at 1,725 feet	75	1,725
Blue shale	10	1,735
Salt water, sand	30	1,765
Blue shale	20	1,785
Oil sand	180	1,965

Crowley Oil and Mineral Company No. 11; sec. 48; Crowley; drilled, 1904; deepened and produced 6,000 barrels daily, January, 1905; 2,300 barrels, October, 1905; abandoned, January, 1908; map No. 325.

Section of Crowley Oil and Mineral Company's well No. 11.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Unknown	....	1,300	Sand, not very hard, oil showing	30	1,790
Gumbo	150	1,450	Hard sand, iron pyrites, shells, slight oil showings	40	1,830
Rock, sand, and gumbo	150	1,600	Sand, not very hard	30	1,860
Salt-water sand	95	1,695	Good oil sand, not very hard; iron pyrites and shell	30	1,890
Gumbo	25	1,720	Gumbo	25	1,915
Soft sand, no oil; looks salty	10	1,730	Good oil sand; fairly hard	50	1,965
Gumbo	10	1,740			
Hard sand with pyrite, no oil	20	1,760			

Screen (Lane No. 40), 2½-inch, 82 feet; 3-inch, 126 feet.

Crowley Oil and Mineral Company No. 12; sec. 48; Crowley; drilled, summer, 1905; 2,000 barrels, July, 1905; deepened and yielded 4,000 barrels, November, 1905; map No. 342. Shells between 1,630 and 1,690 feet: *Rangia* cf. *johnsoni* but probably new, *Rangia cuneata*, *Olivella*, *Natica*.

Section of Crowley Oil and Mineral Company's well No. 12.

[Lake Grow, driller.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	60	60	Oil sand	6	1,445
Water, sand, and gravel	215	275	Blue shale	29	1,475
Quicksand	800	1,075	Sand, gas, salt water	95	1,570
Blue shale	275	1,350	Blue shale	36	1,606
Gravel and shale	76	1,426	Oil sand, hard at first, softer below	90	1,696
Blue shale	15	1,439	Blue shale, with shell	10	1,706

Screen (Geddy No. 60), 101 feet; oil turned into tank May 12, 1904.

A detailed statement of the lower oil-sand bed is as follows:

	Feet.
Fine white sand	20
Sandy shale with shell fragments	10
Fine white sandy shale with shells	10
Fine white sand with wood fragments and shells	10
Fine white sand without wood	10
Sand, fine, more shell fragments	10
Very fine white sand; traces of pyrite	10

Crowley Oil and Mineral Company No. 13; sec. 48; Crowley; operating 1904-5; map No. 317.

Section of "deepened" portion of Crowley Oil and Mineral Company's well No. 13.

[I. B. Grow, driller.]

	Thickness.	Depth.
	Feet.	*Feet.*
Old well	....	1,903
Gumbo	21	1,924
Very hard oil sand	100	2,024

Screen (Lane), 2½-inch, 60 feet; 3-inch, 40 feet, June 4, 1905.

Crowley Oil and Mineral Company No. 14; sec. 48; Crowley; drilled since 1904; producing and deepened in 1905; map No. 418.

Section of Crowley Oil and Mineral Company's well No. 14.

[I. B. Grow, driller.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	40	40	Rock, shell, and gumbo	240	1,440
Quicksand and gravel	718	758	Oil sand	10	1,450
Gumbo	42	800	Gumbo	90	1,540
Gravel, shell, and water sand	120	920	Hard shell and gumbo	15	1,555
Gumbo	250	1,170	Oil sand	120	1,675
Sand and gravel	30	1,200	Gumbo	8	1,683

Screen, 4½-inch, 124 feet.

Crowley Oil and Mineral Company No. 15; sec. 47; Latreille; "old well on the hill;" referred to by Harris in Rept. Louisiana Geol. Survey for 1902, p. 269, and by Hayes and Kennedy in Bull. U. S. Geol. Survey No. 212, p. 129; deepened from 1,600 to 2,474 feet, March, 1905; reached "oil sand," producing 300 barrels of oil and 6,000 barrels of salt water, the latter soon drowning out the oil; known also as the Crowley Latreille No. 1; map No. 237. No specimens were obtained from the deeper portion of this well, but the shallower part, less than 1,600 feet, yielded plenty of *Rangia johnsoni* and hence was well down in late Tertiary beds.

Section of deepened portion of Crowley Oil and Mineral Company's well No. 15.

[Drilling ascribed to Lake Grow and George Little.]

	Thickness.	Depth.
	Feet.	*Feet.*
Gumbo	20	1,620
Pyrite and shell rock	5	1,625
Shells, with very little sand	120	1,745
Gumbo	15	1,760
Blue limestone (or slate ?) and two small sand "cavities," one 3 and one 2 feet thick	60	1,820
Compact flint sand	40	1,860
Blue limestone (or slate ?) with one 4-foot and one 2-foot sand "cavity" (pocket ?)	80	1,940
Fine white water sand	30	1,970
Blue limestone or slate	80	2,050
Coarse white water sand	90	2,140
Blue shale with shells, pyrite, and some sand	70	2,210
Very fine water sand, with some shells	85	2,295
Very hard rock, with some pyrite and shells	6	2,301
Oil sand, with pyrite and shells	173	2,474

Crowley Oil and Mineral Company No. 17; sec. 48; Crowley; 2,000 feet north of the field; drilling, fall, 1905; 6-inch set at 1,800 feet; twisted off, December, 1905; not productive; map No. 318.

Crowley Oil and Mineral Company No. 18; sec. 48; Crowley; drilled, spring, 1906; 400 barrels hourly at first and sanded up; 1,200 barrels, on air, April, 1906; deepened, 1907; dry; map No. 319.

Crowley Oil and Mineral Company No. 19; sec. 48; Crowley; drilled, summer, 1906; 4,000-1,500 barrels, July, 1906; map No. 419.

Crowley Oil and Mineral Company No. 20; sec. 48; Crowley; drilled, summer, 1906; 600 barrels, September, 1906; 30 barrels, November, 1907; pumping, November, 1908; map No. 311. *Rangia cuneata* and *Ostrea* were collected between 1,789 and 1,810 feet.

Section of Crowley Oil and Mineral Company's well No. 20.

[J. H. Harrison, driller.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sand and clay	57	57	Rocks	4	1,752
Gravel and bowlders	800	857	Gumbo	60	1,812
Gumbo	180	1,037	Pyrites and gumbo	22	1,834
Gravel and water sand	78	1,115	Soft shale, good oil showing	14	1,848
Gumbo and gravel	130	1,245	Hard gumbo	40	1,888
Bowlders	80	1,325	Hard shale with pyrites	35	1,923
Gumbo	123	1,448	Gumbo	13	1,936
Hard shale	35	1,483	Good oil sand	6	1,942
Pyrites, gumbo, and sand	35	1,518	Shale, pyrites, good oil showing	21	1,963
Gumbo and gravel	230	1,748	Tough gumbo	8	1,971

Screen, 4½-inch, 86 feet.

Crowley Oil and Mineral Company No. 21; sec. 48; Crowley; drilled, summer, 1906; 300 barrels, September, 1906; map No. 343.

Section of Crowley Oil and Mineral Company's well No. 21.

[J. Lee, driller.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	40	40	Gumbo	47	1,447
Sand and gravel	660	700	Shale and sand	68	1,515
Gumbo	20	720	Gumbo	63	1,578
Sand and some gumbo	542	1,262	Oil sand	20	1,598
Gumbo	45	1,307	Gumbo	10	1,608
Shell and gumbo	93	1,400	Oil sand and gumbo	60	1,668

Screen from 1,660 to 1,662 feet.

Crowley Oil and Mineral Company No. 22; sec. 48; Crowley; drilled, fall, 1906; flowed 300 barrels daily, October, 1906; deepened, summer, 1907; 20 barrels, June, 1907; map No. 341.

Section of Crowley Oil and Mineral Company's well No. 22.

[J. Lee, driller.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Not given	40	40	Sand and gravel with shells	45	1,120
Sand and gravel	690	730	Gumbo	95	1,215
Gumbo	20	750	Sand and gravel	67	1,282
Sand and gravel	280	1,030	Gumbo	93	1,375
Gumbo	45	1,075	Gravel and some sand	125	1,500

Total depth of well, 1,563 feet. Screen, 4½-inch, 52 feet.

Crowley Oil and Mineral Company No. 23; sec. 48; Crowley; drilled, fall, 1906; 150 barrels, October, 1906; map No. 410.

Section of Crowley Oil and Mineral Company's well No. 23.

[J. H. Harrison, driller.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sand and clay	70	70	Bowlders and gravel	50	1,370
Sand and gravel	644	724	Hard gumbo and rock	70	1,440
Gumbo	70	784	Gravel and sand	80	1,520
Sand	105	889	Hard gumbo	85	1,605
Gumbo	125	1,014	Pyrites and good oil showing	25	1,630
Sand and gravel	43	1,057	Gumbo and hard shale	14	1,644
Soft gumbo	82	1,139	Oil sand	12	1,656
Sand and gravel	61	1,200	Gumbo	21	1,677
Gumbo	120	1,320	Sand and gravel	10	1,687

Screen, 4½-inch, 64 feet.

Crowley Oil and Mineral Company No. 24; sec. 48; Crowley; drilled, fall, 1906; flowed at 800-barrel rate at first and suddenly stopped; deepened, 1906; map No. 315. Specimens of *Mulinia quadricentennialis* were collected from 1,923 to 1,935 feet.

Section of Crowley Oil and Mineral Company's well No. 24.

[J. O. Lee, driller.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	40	40	Gumbo	6	1,890
Sand and gravel	793	833	Oil sand	70	1,960
Gumbo	87	920	Set 62 feet of 4½-inch screen.		
Sand and gravel, with some gumbo	136	1,056	Shale	10	1,970
Gumbo and some rock	113	1,169	Pyrites and sand	54	2,024
Oil showing	10	1,179	Set 63.5 feet of 3-inch screen.		
Gumbo, with some sand	705	1,884			

Crowley Oil and Mineral Company No. 25; no complete log obtained, but Reinecke collected a large number of fossils from the overflow between 2,400 and 2,650 feet; fossils identified by C. J. Maury: *Rangia johnsoni*, common from 1,960 to 2,650 feet; *Mulinia quadricentennialis*, 1,830 to 1,860 feet; *Amnicola*, 2,440 to 2,500, 2,528 to 2,565, 2,585 to 2,650 feet; *Ostrea*, 2,468 to 2,500 feet; *Neverita duplicata*, 2,468 to 2,500 feet; *Spisula quadricentennialis*, 2,585 to 2,600 feet.

Crowley Oil and Mineral Company No. 26; sec. 48; Crowley; drilled, winter, 1906–7; 300 barrels, February, 1907; producing, 1908; map No. 319. The following fossils were collected: *Rangia cuneata*, 1,660 feet; *Mulinia quadricentennialis*, 1,680 to 1,880 feet.

Crowley Oil and Mineral Company No. 27; sec. 48; Crowley; drilled, summer, 1907; dry.

Crowley Oil and Mineral Company No. 28; sec. 48; Crowley; drilled, spring, 1907; 200 barrels on pump; not producing, 1908; map No. 321.

Crowley Oil and Mineral Company No. 29; sec. 48; Crowley; drilled, summer and fall, 1907; 30 barrels, November, 1907; map No. 310.

Crowley Oil and Mineral Company No. 30; sec. 48; Crowley; drilled, summer, 1907; map No. 339.

Crowley Oil and Mineral Company No. 31; sec. 48; Crowley; drilled, summer, 1907; map No. 340.

Crowley Oil and Mineral Company No. 32; sec. 48; Crowley; drilled, fall, 1907; 300 barrels, October, 1907; map No. 345.

Crowley Oil and Mineral Company No. 33; sec. 48; Crowley; drilled, fall, 1907; dry; map No. 344.

Crowley Oil and Mineral Company No. 35; sec. 48; drilled, spring, 1908; producing, 1908; map No. 323.

Crowley Oil and Mineral Company No. 36; sec. 48; Crowley; drilled, spring, 1908; salt water; map No. 324.

Crowley Oil and Mineral Company No. 37; sec. 48; Crowley; drilling, fall, 1908; map No. 306.

Crowley Oil and Mineral Company No. 38; sec. 48; Crowley; drilled, summer, 1908; producing, November, 1908; map No. 305.

Crowley Oil and Mineral Company No. 39; sec. 48; Crowley; drilling, summer and fall, 1908; map No. 304.

Crowley Petroleum Company No. 1; sec. 46; Bettison half acre; producing, 1904; deepened, 1906; abandoned, 1906; map No. 131.

Crusell (et al.) No. 1; sec. 47; Arnaudet; operating, January, 1907; abandoned, 1908; map No. 277.

Crusell & Bass No. 1; sec. 47; Arnaudet; drilled, fall, 1906; salt water; abandoned, spring, 1907; map No. 278.

Crusell No. 2; sec. 47; Arnaudet; location only known; map No. 279.

Duson & Lyons No. 1; sec. 45; drilled, summer, 1907; small pumper; abandoned, December, 1907; map No. 395. Fossils collected by L. Reinecke, identified by C. J. Maury: *Rangia cuneata*, 1,530 to 1,860 feet; *Spisula* cf. *quadricentennialis*, 1,860 to 1,910 feet.

Section of Duson & Lyons's well No. 1, sec. 45.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	30	30
Sand	450	480
Coarse, greenish quartz sand	100	580
Sand	160	740
Rather fine sand	40	780
Gumbo	20	800
Sand with some clay and limestone flakes	40	840
Gumbo	40	880
Coarse sand with some blue clay	40	920
Apparently clay	50	970
Blue brittle clay, with fragments of white clay, not calcareous	60	1,030
Sand, pyrite, and some clay	20	1,050
Blue clay, like second bed above	20	1,070
Sand with pyrite, like second bed above	20	1,090
Gumbo?	110	1,200
Fine white sand, with some pyrite	100	1,300
Shale and some rock fragments	60	1,360
Shale, with few rock fragments	70	1,430
Shaly sand with sandstone fragments	100	1,530
Broken shells, with gravel and shale	50	1,580
Shells, with limestone fragments	100	1,680
Sand, with wood fragments	20	1,700
Not given	80	1,780
Pyrite and broken limestone	15	1,795
Gumbo	5	1,800
Pyrite and broken sandstone fragments	20	1,820
Sand, some pyrite, plenty of shells	90	1,910
Blue clay, with much pyrite	15	1,925

Duson & Lyons No. 1; sec. 47; King tract; drilled, fall, 1907; salt water, October, 1907; abandoned.

Duson No. 2; sec. 45; Schultz; drilled, fall, 1907; abandoned, December, 1907; map No. 396.

Duson No. 3; sec. 45; Schultz; no additional data; map No. 397.

Equitable No. 1; Rowson & Haber; sec. 46; drilled before 1905; long extinct; map No. 136.

Eunice-Crowley Oil Company No. 1; sec. 42; Heywood-Acadia lease; drilled, fall, 1903; near site of No. 33.

Evangeline Oil Company No. 1; sec. 47; Evangeline; drilled, fall, 1904; from September 8 to October 1 flowed 260,000 to 300,000 barrels; 1,000 barrels, on air; November, 1905; not producing, 1908; map No. 288.

Evangeline Oil Company No. 2; section 47; Evangeline; drilled, fall, 1904; 5,000 to 7,000 barrels; salt water, September, 1905; abandoned, 1906; map No. 285.

Evangeline Oil Company No. 3; sec. 47; Evangeline; drilled, fall, 1904; salt water; 1,500 barrels on air; July, 1905; not producing, 1908; map No. 283.

Evangeline Oil Company No. 3′; sec. 47; Evangeline; an old producer, abandoned in 1908; map No. 287.

Evangeline Oil Company No. 4; sec. 46; Producers-Evangeline; drilled, spring, 1905; 10 barrels, November, 1905; deepened, 1906; map No. 99.

Evangeline Oil Company No. 5; sec. 46; Producers-Evangeline; dry hole, abandoned, 1905; map No. 98.

Evangeline Oil Company No. 6; sec. 47; Evangeline; drilled, summer, 1905; 2,000 barrels on air; salt water, September, 1905; abandoned, May, 1908; map No. 284.

Evangeline Oil Company No. 7; sec. 47; Evangeline; drilled, spring, 1906; salt water, abandoned; map No. 281.

Evangeline Oil Company No. 8; sec. 47; Evangeline; drilled, summer, 1906; 800 barrels on air; deepened, fall, 1907; abandoned, 1908; map No. 286.

Section of Evangeline Oil Company's well No. 8.

	Thickness.	Depth.
	Feet.	*Feet.*
Yellow clay	20	20
Water sand	10	30
Sand and clay beds	90	120
Beds of loose gravel and sand	780	900
Shale and gumbo	860	1,760
Oil and gas sands	60	1,820
Oil sand and pyrite	80	1,900

Evangeline Oil Company No. 9; sec. 47; Evangeline; drilled, fall, 1906; 200 barrels on air, 1906; map No. 282.

Section of Evangeline Oil Company's well No. 9.

	Thickness.	Depth.
	Feet.	*Feet.*
Yellow clay	30	30
Water sand and streaks of gumbo	40	70
Sand and gravel	670	740
Gumbo	80	820
Strata of salt-water sand, gumbo, and shale	920	1,740
Tough gumbo	40	1,780
Pyrite and oil sand in thin strata	195	1,975

Franklin Oil Company No. 1; east of the field; drilled, fall, 1906; traces of oil; abandoned, March, 1907. Fossils, collected by L. Reinecke, identified by C. J. Maury: *Rangia cuneata*, 784–876, 1,238–1,322, 1,431–1,621 feet; *Rangia johnsoni*, 2,183–2,584 feet; *Arca* (fragment), 1,238–1,322 feet; *Ostrea*, 1,238–1,322 feet; *Amnicola*, 1,238–1,322, 2,183–2,204, 2,480–2,497, 2,654–2,664 feet; *Bittium*, 2,505–2,524 feet.

Section of Franklin Oil Company's well No. 1.

[W. Brown, driller.]

	Thickness.	Depth.
	Feet.	*Feet.*
Fine yellowish silty clay, becoming greenish toward bottom	175	175
Fine greenish sand, somewhat silty to 314 feet, then decidedly silty, but becoming coarser below	701	876
Fine green sand, broken flinty hard flakes	43	919
Sandy clay, with numerous shell fragments and some flint pebbles	84	1,003
Fine green sand, with pure white quartz grains and black specks; wood and a few shell fragments below	150	1,153
Tough blue clay, containing flint pebbles, some sand, and shell fragments	257	1,410
Tough blue sandy clay, with plenty of shells at 1,440–1,473 and 1,495–1,510 feet; fragments below may have been picked up by drill from beds above, according to driller	190	1,600
Generally white sand (becoming clayey with shells between 1,623 and 1,640 feet)	85	1,685
No record	25	1,710
Tough blue clay with pieces of bark and shell fragments, becoming sandy below	39	1,749
Blue clay with vegetable fiber	42	1,791
No record	22	1,813
White sand with flint pebbles, gravelly below (shells, 1,856–1,898 feet)	190	2,003
No record	10	2,013
Greenish, rather coarse sand, with flint and quartzite pebbles	61	2,074
No record	109	2,183
Green marl with plenty of shells	10	2,193
Green shell marl, shaly	11	2,204
No record	22	2,226
Blue marly clay, many shells	11	2,237
No record	21	2,258
Crumbly blue clay, hard to dissolve in water	22	2,280
No record	104	2,385
Blue tough shell marl	13	2,397
No record	32	2,429
Greenish sandy marl, very calcareous, with shells	30	2,459
No record	21	2,480
Green marl, full of shells	12	2,492
Fine greenish marly sand, few shells	120	2,612
Hard limestone	6	2,618
Sand with good oil indications	28	2,646
White calcareous sand, with shells	10	2,656
Sand	36	2,692

Getty No. 1; sec. 46; Getty; interesting as being a producer of usual depth (1,700–1,800 feet), 1904; deepened to test lower strata to 2,400 feet. Said to make 100 barrels oil, with about 5,000 barrels of salt water, daily; not a producer in 1908; map No. 73.

Guarantee No. 1; sec. 46; Guarantee; drilled, 1902; producing, 1903; map No. 133. (For section, see Bull. U. S. Geol. Survey No. 282, p. 96.)

Gulf Refining Company No. 1 (Jennings-Heywood Oil Syndicate No. 56); sec. 46; Syndicate-Clement; drilled, spring, 1908; 500 barrels, April, 1908; map No. 56.

Gulf Refining Company No. 1 (J. H. O. S. No. 4); sec. 41; Syndicate Fee Simple; drilled, spring, 1905; reported salt water, 1905; 3,500 barrels on air; map No. 149.

Gulf Refining Company No. 1; sec. 46; drilled, 1908; map No. 80.

Gulf Refining Company No. 2 (J. H. O. S. No. 57); sec. 46; Syndicate-Clement; drilled, spring, 1908; 1,000 barrels, April, 1908; producing, November, 1908; map No. 57.

Gulf Refining Company No. 2 (J. H. O. S. No. 7); sec. 47; Arnaudet; 100 feet from Heywood No. 1; drilled, spring, 1906; 10,000-barrel gusher; some salt water; producing, 1908; map No. 301.

Gulf Refining Company No. 3 (J. H. O. S. No. 61); sec. 46; Syndicate-Clement; drilled, spring, 1908; 800 barrels on air, May, 1908; producing, November, 1908; map No. 59.

Gulf Refining Company No. 3; sec. 47; Arnaudet; history not known; map No. 336.

Gulf Refining Company No. 4 (J. H. O. S. No. 12); sec. 47; Arnaudet; drilled, summer, 1906; produced 500 barrels and went to salt water, July, 1906; 100-barrel pumper, 1907; producing, November, 1908; map No. 326.

Gulf Refining Company No. 5 (J. H. O. S. No. 37); sec. 41; Syndicate Fee Simple; drilled, summer, 1907; 2,500 barrels on air; producing, 1908; map No. 150.

Gulf Refining Company No. 5; sec. 46; Syndicate-Clement; drilled, spring, 1908; 500 barrels on air, May, 1908; map No. 60.

Gulf Refining Company No. 6 (J. H. O. S. No. 14); sec. 47; Arnaudet; drilled, summer, 1906; flowed at 8,000-barrel rate and went to salt water; map No. 292.

Gulf Refining Company No. 7 (J. H. O. S. No. 15); sec. 47; Arnaudet; drilled, summer, 1906; 5,000 barrels and falling rapidly, September, 1906; map No. 294.

Gulf Refining Company No. 7; sec. 46; Syndicate-Clement; salt water; not producing, 1908; map No. 61.

Gulf Refining Company No. 4 (J. H. O. S. No. 62); sec. 46; Syndicate-Clement; drilled, spring, 1908; salt water, May, 1908; map No. 58.

Gulf Refining Company No. 1 (J. H. O. S. No. 48); sec. 42; Lekelt; drilled, January, 1908; 400 barrels water, February, 1908; producing, November, 1908; map No. 48.

Gulf Refining Company No. 2 (J. H. O. S. No. 51); sec. 42; Lekelt; drilled, spring, 1908; 200 barrels, March, 1908; map No. 45.

Gulf Refining Company No. 2; sec. 46; Jennings-Heywood; drilled, fall, 1908; producing, November, 1908; map No. 123.

Gulf Refining Company No. 3 (J. H. O. S. No. 55); sec. 42; Lekelt; drilled, spring, 1908; salt water, April, 1908; map No. 44.

Gulf Refining Company No. 3 (Jennings Oil Company, Clement No. 13); sec. 46; drilled, spring and summer, 1908; producing, November, 1908; map No. 69.

Gulf Refining Company No. 4 (Jennings Oil Company No. 14); sec. 46; Jennings-Clement; drilled, spring, 1908; 200 barrels on air, May, 1908; map No. 67.

Gulf Refining Company No. 4 (J. H. O. S. No. 59); sec. 42; Lekelt; drilled, spring, 1908; 150 barrels, May, 1908; map No. 49.

Gulf Refining Company (Wilkins) No. 4; sec. 47; Valée arpent; drilled, summer, 1905; flowed 3,000 barrels and sanded up, September, 1905; map No. 258.

Gulf Refining Company No. 5 (Jennings Oil Company No. 15); sec. 46; Jennings-Clement; drilled, summer, 1908; 100 barrels, July, 1908; producing, November, 1908; map No. 66.

Gulf Refining Company No. 5 (J. H. O. S. No. 13); sec. 47; Arnaudet; drilled, summer, 1906; reported salt water; operating, 1908; map No. 327.

Gulf Refining Company No. 5; sec. 42; Lekelt; drilled, spring, 1908; small producer; map No. 50.

Gulf Refining Company No. 6; sec. 46; Jennings-Heywood; drilled, summer, 1908; 150 barrels, September, 1908; pumping, November, 1908; map No. 79.

Gulf Refining Company No. 6; sec. 42; Lekelt; drilled, spring, 1908; small producer; map No. 51.

Gulf Refining Company No. 6 (Keoughan et al. No. 2); sec. 46; Zeigler; producing, November, 1908; map No. 115.

Gulf Refining Company No. 7; sec. 46; Jennings-Heywood; drilled, fall, 1908; 100 barrels, October, 1908; pumping, November, 1908; map No. 78.

Gulf Refining Company No. 8; sec. 46; Zeigler; drilled, fall, 1908; producing, November, 1908; map No. 114.

Gulf Refining Company No. 8; sec. 46; Jennings Oil Company, Clement; drilling, 1908; 350 barrels, October,; map No. 68.

Gulf Refining Company No. 9; sec. 46; Jennings-Clement; drilled, fall, 1908; 100 barrels, November, 1908; map No. 108.

Gulf Refining Company No. 9 (J. H. O. S. No. 17); sec. 47; Arnaudet; drilled, Septem, ber, 1906; 95 per cent salt water, October, 1906; packer inserted and 300 barrels oil daily, November, 1906; not producing, 1908; map No. 334.

Gulf Refining Company No. 10 (J. H. O. S. No. 19); sec. 47; Arnaudet; drilled, fall, 1906; producing, November, 1908; map No. 380.

Gulf Refining Company No. 10 (J. H. O. S. No. 42); sec. 41; Syndicate Fee Simple; drilled, fall, 1907; 200 barrels, December, 1907; map No. 151.

Gulf Refining Company No. 10; sec. 46; Jennings-Clement; drilled, fall, 1908; 75 barrels, November, 1908; map No. 82.

Gulf Refining Company No. 11 (J. H. O. S. No. 20); sec. 47; Arnaudet; drilled, fall-1906; 400 barrels, November, 1906; producing, November, 1908; map No. 378.

Gulf Refining Company No. 11 (Jennings-Clement No. 8); sec. 46; Jennings-Clement; drilled, fall, 1908; operating in November, but reported as dry in December, 1908; map No. 76.

Gulf Refining Company No. 12; sec. 46; Jennings-Clement; drilled, fall, 1908; pumping, November, 1908; map No. 71.

Gulf Refining Company No. 12 (J. H. O. S. No. 21); sec. 47; Arnaudet; drilled, fall, 1906; 1,200 barrels on air, November, 1906; producing, November, 1908; map No. 295.

Gulf Refining Company No. 13; sec. 46; Jennings-Clement; drilled, fall, 1908; pumping, November, 1908; map No. 72.

Gulf Refining Company No. 13 (J. H. O. S. No. 50); sec. 41; Syndicate Fee Simple; drilled, February, 1908; 1,000 barrels, March, 1908; being worked November 8, 1908; map No. 53.

Gulf Refining Company No. 14 (J. H. O. S. No. 53); sec. 41; Syndicate Fee Simple; drilled, spring, 1908; 1,000 barrels, April; producing, November, 1908; map No. 54.

Gulf Refining Company No. 14; sec. 46; Jennings-Clement; drilling, November, 1908; map No. 70.

Gulf Refining Company No. 15 (J. H. O. S. No. 54); sec. 41; Syndicate Fee Simple; drilled, spring, 1908; cleaning, November, 1908; map No. 159.

Gulf Refining Company No. 15 (J. H. O. S. No. 35); sec. 47; Arnaudet; drilled, summer, 1907; producing, November, 1908; map No. 296.

Gulf Refining Company No. 15 (J. H. O. S. No. 31); sec. 47; Martin; drilled; spring, 1907; 150 barrels, April, 1907; deepened, summer, 1907; producing, 1908; map No. 387.

Gulf Refining Company No. 15; sec. 46; Heywood Oil Corporation; drilled, fall, 1908; producing, November, 1908; map No. 102.

Gulf Refining Company No. 16 (Bass No. 16); sec. 47; Guffey Petroleum Company; drilled, spring, 1906; 3,000 barrels, May, 1906; producing, 1908; map No. 358.

Gulf Refining Company No. 16; sec. 41; Syndicate Fee Simple; location only known; map No. 160.

Gulf Refining Company No. 16 (J. H. O. S. No. 32); sec. 47; Arnaudet; drilled, summer, 1907; producing, November, 1908; map No. 297.

Gulf Refining Company No. 16; sec. 46; Jennings-Clement; drilled, fall, 1908; pumping, November, 1908; map No. 81.

Gulf Refining Company No. 17 (J. H. O. S. No. 36); sec. 47; Arnaudet; drilled, summer, 1907; 500 barrels, August, 1907; producing, November, 1908; map No. 291.

Gulf Refining Company No. 17 (J. H. O. S. No. 60); sec. 41; Syndicate Fee Simple; drilled, spring, 1908; 500 barrels on air, May, 1908.

Gulf Refining Company No. 18 (J. H. O. S. No. 42); sec. 47; Arnaudet; drilled, fall, 1907; 200 barrels, December, 1907; not producing, November, 1908; map. No. 293.

Gulf Refining Company No. 18; sec. 41; Syndicate Fee Simple; no data; not producing, November, 1908; map No. 161.

Gulf Refining Company No. 19; sec. 47; Arnaudet; drilled, summer, 1908; producing, November, 1908; map No. 299.

Gulf Refining Company No. 20; sec. 47; Guffey Petroleum Company; drilled, fall, 1907; producing, 1908; map No. 359.

Gulf Refining Company No. 20 (J. H. O. S. No. 68); sec. 41; Syndicate Fee Simple; drilled, summer, 1908; 100 barrels; not producing, November, 1908; map No. 153.

Gulf Refining Company No. 21; sec. 41; Syndicate Fee Simple; drilled, summer, 1908; salt water, 1908; map No. 156.

Gulf Refining Company No. 22 (J. H. O. S. No. 70); sec. 41; Syndicate Fee Simple; drilled, summer, 1908; salt water, 1908; map No. 158.

Gulf Refining Company No. 23 (J. H. O. S. No. 71); sec. 41; Syndicate Fee Simple; drilled, summer, 1908; 70 barrels and much salt water, August, 1908; map No. 52.

Gulf Refining Company No. 24 (J. H. O. S. No. 72); sec. 41; Syndicate Fee Simple; 200 barrels, fall, 1908; producing, November, 1908; map No. 55.

Gulf Refining Company No. 25; sec. 41; Syndicate Fee Simple; drilled, summer, 1908; salt water; map No. 147.

Gulf Refining Company No. 26; sec. 41; Syndicate Fee Simple; drilled, fall, 1908; salt water; map No. 154.

Gusher Oil Company; old well in northwest corner sec. 48, given on Hayes and Kennedy's map of the field as No. 1.

Haifleigh No. 1; sec. 47; Attakapas; reported as being deepened, October, 1907; salt water, November, 1907; map No. 273.

Haifleigh No. 2; sec. 47; Latreille; location only known; map No. 233.

Haifleigh No. 3; sec. 47; Attakapas; drilled, fall, 1907; salt water, November, 1907; map No. 270.

Harry No. 1; sec. 47; Valée arpent; drilled, spring, 1908; abandoned; map No. 260.

Heywood Brothers & Chaddock No. 1; sec. 47; Morse; drilled, summer, 1903; map No. 370.

Heywood Oil Company No. 1; sec. 42; Acadia; map No. 36.

Heywood (Bass) No. 1; map No. 63.

Heywood Brothers Oil Corporation No. 1; sec. 46; Heywood-Clement; drilled, spring, 1903; produced, 1904–5; map No. 413.

Heywood Brothers Oil Corporation No. 2; sec. 46; Heywood-Clement; drilled, spring, 1907; abandoned, summer, 1908; map No. 103.

Heywood Brothers Oil Corporation No. 3; sec. 46; Heywood-Clement; drilled, summer, 1907; abandoned, summer, 1908; map No. 104.

Heywood Brothers Oil Corporation No. 4; sec. 46; Heywood-Clement; drilled, spring, 1906; 500 barrels, June, 1907; map No. 108 (location of Gulf Refining Company, No. 9).

Heywood Oil Company No. 1; sec. 47; Arnaudet; drilled, fall, 1904; 10,000 barrels, October, 1904; 3,000 barrels, April, 1905; abandoned, 1906; map No. 389.

Heywood Oil Company No. 1; sec. 42; Eunice-Crowley; drilled late in 1907 or early in 1908; 500 barrels, February, 1908; map No. 29.

Heywood Oil Company No. 1; sec. 48; Crowley; drilled, January, 1906; 8,000-barrel gusher, February, 1906; 3,000 barrels, April, 1906; producing, 1908; map No. 424.

Section of Heywood Oil Company's well No. 1, sec. 48, below bottom of 6-inch casing (1,805 feet).

[H. H. Jones, driller.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Gumbo	7	1,812	Rock	4	1,879
Sand	3	1,815	White sandstone	7	1,886
Rock	1	1,816	Soft clay	10	1,896
Oil sand	4	1,820	Gumbo	13	1,909
Gumbo	35	1,855	Oil in streaks (as usual in field)	53	1,962
Oil sand	20	1,875			

Heywood Oil Company No. 1; sec. 45, Lyons; drilled, spring, 1907; salt water, April, 1907; map No. 19.

Heywood Oil Company No. 2; sec. 47; Arnaudet; produced poor oil, 1906; producing, 1908; map No. 392.

Heywood Oil Company No. 2; sec. 48; Crowley; drilled, spring, 1906; 2,000 barrels, May, 1906; map No. 302. Oil is dark and different from that of the best part of the field.

Section of Heywood Oil Company's well No. 2, sec. 48, below depth of 1,818 feet.

[H. H. Jones, driller.]

	Thickness.	Depth.
	Feet.	*Feet.*
Gumbo	38	1,856
Oil sand	8	1,864
Gray clay	31	1,895
Oil sand	15	1,910
Gumbo	26	1,936
Oil sand	32	1,968

Six-inch casing set at 1,843 feet. This well showed fragments of rock from 1,331 feet down, but was especially noteworthy for the rock between 1,450 and 1,495 feet, which it required fifty-two days to penetrate and which used up 150 bits.

Heywood Oil Company No. 2; sec. 42; Acadia; drilled, spring, 1908; 500 barrels, March, 1908; map No. 37.

Heywood Oil Company No. 3; sec. 47; Arnaudet; drilled, summer, 1905; produced 1,200 barrels in four hours, November, 1905; affected No. 4 decidedly; 300 barrels, December, 1905; abandoned, 1908; map No. 390.

Heywood Oil Company No. 3; sec. 48; Crowley; drilled, summer, 1906; 3,000 barrels June, 1906; pumping, November, 1908; drilled, map No. 312.

Section of Heywood Oil Company's well No. 3, sec. 48, below depth of 1,822 feet.

[H. H. Jones, driller.]

	Thickness.	Depth.
	Feet.	*Feet.*
Gumbo	41	1,863
Oil sand	8	1,871
Pyrites	33	1,904
Oil sand	6	1,910
Gumbo	21	1,931
Oil sand	4	1,935
Gumbo	13	1,948
Oil	14	1,962

Six-inch casing set at 1,849 feet.

Heywood Oil Company No. 3; sec. 42; Acadia; drilled, spring, 1908; 200 barrels, May, 1908; producing, November, 1908; map No. 33.

Heywood Oil Company No. 3; sec. 42; Eunice-Crowley; drilled, spring, 1908; map No. 30.

Heywood Oil Company No. 4; sec. 47; Arnaudet; drilled, spring, 1905; 8,000 barrels, June, 1905; 4,800 barrels, November, 1905; stopped flowing, December, 1905; deepened, 1907; map No. 391.

Heywood Oil Company No. 4; sec. 48; Crowley; drilled, summer, 1906; salt water; deepened, 1907; this or a well in about the same location producing in 1908; map No. 322.

Heywood Oil Company No. 4; sec. 42; Acadia; drilled, spring, 1908; 175 barrels, May, 1908; map No. 23.

Heywood Oil Company No. 4; sec. 42; Eunice-Crowley; drilled, spring; 1908; 175 barrels, May, 1908; map No. 32.

Heywood Oil Company No. 5; sec. 47; Arnaudet; drilled, summer, 1906; 4,000-barrel gusher for four days and then sanded up; producing, 1908; map No. 393.

Heywood Oil Company No. 5; sec. 48; Crowley; drilled, summer, 1906; salt water, August, 1906; map No. 314.

Heywood Oil Company No. 5; sec. 42; Acadia; drilled, spring, 1908; 250 barrels, April, 1908; map No. 25.

Heywood Oil Company No. 5; sec. 42; Eunice-Crowley; drilled, spring, 1908; salt water, May, 1908; map No. 31.

Heywood Oil Company No. 6; sec. 47; Arnaudet; drilled, fall, 1906; 400 barrels, November, 1906; abandoned, 1908; map No. 388.

Heywood Oil Company No. 6; sec. 42; Acadia; drilled, spring, 1908; 200 barrels, April, 1908; not producing, November, 1908; map No. 34.

Heywood Oil Company No. 6; sec. 42; Eunice-Crowley; drilled, spring, 1908; 100 barrels, 1908; producing, November, 1908; map No. 46.

Heywood Oil Company No. 6; sec. 48; Crowley; drilled, summer, 1906; 1,000 barrels for one day only, July, 1906; map No. 308.

Heywood Oil Company No. 7; sec. 42; Acadia; drilled, fall, 1908; 100 barrels, November, 1908; map No. 35.

Heywood Oil Company No. 7; sec. 42; Eunice-Crowley, drilled, summer, 1908; salt water, July, 1908; map No. 42.

Heywood Oil Company No. 7; sec. 48; Crowley; drilled, fall, 1906, to spring, 1907; map No. 313.

Heywood Oil Company No. 8; sec. 42; Eunice-Crowley; drilled, summer, 1908; 100 barrels, July, 1908; producing, November, 1908; map No. 40.

Heywood Oil Company No. 8; sec. 48; Crowley; drilled, fall, 1906; 100 barrels on air, December, 1906; abandoned, March, 1907; map No. 309. Fossils collected by L. Reinecke and identified by C. J. Maury: *Mulinia mamouensis* n. s., 2,050, 2,115–2,131 feet; *Ostrea*, 2,050 feet; *Turritella*, 2,050 feet; *Divaricella*, 2,050 feet.

Section of Heywood Oil Company's well No. 8, sec. 48.

	Thickness.	Depth.
	Feet.	*Feet,*
Clay	120	120
Sand and gravel	480	600
Gumbo	40	640
Sand and gravel	165	805
Gumbo, sand, and gravel	837	1,642
Hard, rough stones, pyrite, and shells	205	1,847
Gumbo	6	1,853
Hard matter	7	1,860
Gumbo	80	1,940
Rock (gas)	35	1,975
Gumbo and sand	43	2,018
Sand (traces of oil)	7	2,025
Rock	15	2,040
Sand, gumbo, shells, pyrite. Gas blew out through hole in casing at 2,050 feet, erupting fragments of blackish shale with shells, blue sandy limestone with pyrite and shells, and blue clay	75	2,115
Black shaly clay	16	2,131

Heywood Oil Company No. 9; sec. 48; Crowley; drilled, winter, 1906–7; not producing, November, 1908; map No. 303.

Heywood Oil Company No. 9; sec. 42; Eunice-Crowley; drilled, summer, 1908; dry, August, 1908; map No. 41.

Heywood Oil Company No. 10; sec. 48; Crowley; drilled, summer, 1907; blowing gas July, 1907; map No. 307.

Hill No. 1; sec. 45; Schultz; drilling, January, 1908; 500 barrels, February, 1908; map No. 403.

Hill (C. D.) No. 1; sec. 47; Kneiffe; drilled, fall, 1907; 150 barrels, November, 1907; abandoned, 1908; map No. 243.

Hill (C. D.) No. 2; sec. 47; Kneippe; drilled, fall, 1907; 150 barrels, October, 1907; abandoned; map No. 250.

Hill (C. D.) No. 4; sec. 46; Guarantee; drilled, fall, 1907; dry; map No. 134.

Hill (C. D.) No. 5; sec. 46; Bettison half acre; drilled, spring, 1908; salt water, March, 1908; map No. 132.

Home Oil Company, east of Jennings, at cemetery; given as No. 9 on Hayes and Kennedy's map; at least 1,700 feet deep; no results.

Home Oil Company No. 1; sec. 45; Conklin; drilled before 1904; map No. 400.

Home Oil Company; sec. 47: Producers half acre; drilled, fall, 1904; 16,000-barrel gusher, October 1, 1904; ceased to flow, December, 1904, but always responds to the bailer; map No. 348.

Interstate No. 1; sec. 45; Schultz; not producing, 1908; map No. 18.

Interstate No. 2; sec. 45; drilled, spring and summer, 1908; not producing, November, 1908; map No. 13.

Ismerie No. 2; sec. 45; Schultz; drilled, spring, 1908; salt water; map No. 14.

Ismerie (Duson & Lyons) No. 1; sec. 45; Schultz; drilled, spring, 1908; 1,200 barrels, March, 1908; map No. 423.

Ismerie No. 3; sec. 45; Schultz; abandoned, May, 1908; map No. 11.

Jaenke (F. R.) No. 2; sec. 41; syndicate Fee Simple; drilled, summer, 1904; found 45 feet of the "sand," extending the known field 300 feet to the south; produced 200 barrels, 1904; map No. 145.

Jennings Oil Company No. 1; sec. 46; Jennings; drilled, summer, 1901; first well in the field; produced some in 1901 and 1902; sand said to be 1,800 feet deep; map No. 120.

Jennings Oil Company No. 2; sec. 46; Jennings-Clement; drilled, spring, 1904; 6-inch casing set at 1,800 feet; gushed and burned fiercely from July 15 to July 21, 1902; produced, 1903–4; abandoned, 1907; map No. 122.

Jennings Oil Company No. 3; sec. 46; Clement; producing, June, 1903; old screen sidetracked September, 1903; producing, 1904; extinct, 1908; map No. 109.

Jennings Oil Company No. 4; sec. 46; Jennings-Clement; drilled, spring, 1903; operating, 1903–4; map No. 124.

Jennings Oil Company No. 5; sec. 46; Jennings-Clement; producing, 1903; deepened, 1906; blew out and destroyed derrick; abandoned, 1908; map No. 141.

Jennings Oil Company No. 7; sec. 46; Jennings-Clement; drilled, spring, 1906; producing, 1906; abandoned, 1908; site of Savage No. 1; map No. 432.

Jennings Oil Company No. 8; sec. 46; Jennings-Clement; drilled, spring, 1906; dry, June, 1906; map No. 77.

Jennings Oil Company No. 10; sec. 46; Jennings-Clement; drilled, summer, 1906; salt water; map No. 121.

Jennings Oil Company No. 11; sec. 46; Jennings-Clement; drilled, fall, 1906; 150 barrels, October, 1906; abandoned, 1908; map No. 426.

Jennings Oil Company No. 12; sec. 46; Jennings Fee Simple; drilled, summer, 1907; 350 barrels, November, 1907; map No. 92.

Jennings-Heywood Oil Syndicate No. 1; an old test well put down southwest of the field in 1902.

Jennings-Heywood Oil Syndicate No. 2; sec. 46; Syndicate's half acre on east margin of the section; drilled, 1902; producing, 1903, abandoned, map No. 130.

Jennings-Heywood Oil Syndicate No. 5 (Gulf Refining Company No. 1); sec. 47; Rex; drilled, fall, 1905; 1,500 barrels on air, October, 1905; producing, 1907; not producing, 1908; map No. 257.

Jennings-Heywood Oil Syndicate No. 6 (Gulf Refining Company No. 2); sec. 41; Syndicate Fee Simple; drilled early in 1906; hot salt water, July, 1906; deepened, 1907; not producing, 1908; map No. 152.

Jennings-Heywood Oil Syndicate No. 8; sec. 47; Arnaudet; drilled, spring, 1906; abandoned, June, 1907; not producing, 1908; map No. 300.

Jennings-Heywood Oil Syndicate No. 11 (Gulf Refining Company No. 2); sec. 47; Rex; drilled, summer, 1906; 500 barrels, October, 1906; producing November, 1908; practically site of "Rayne Planters No. 2" of Bull. U. S. Geol. Survey, No. 282; map No. 239.

Jennings-Heywood Oil Syndicate No. 16; sec. 47; Arnaudet; drilled, summer, 1906; 3,000 barrels at first, then sanded up; map No. 444.

Jennings-Heywood Oil Syndicate No. 18; sec. 47; Arnaudet; drilled, fall, 1906; abandoned, fall, 1907; map No. 381.

Jennings-Heywood Oil Syndicate No. 21; sec. 47; Arnaudet; drilled, fall, 1906; 1,200 barrels on air, November, 1906; map No. 443.

Jennings-Heywood Oil Syndicate No. 22; sec. 47; Arnaudet; drilled, fall, 1906; terrific blowout, November, 1906; salt water, December; map No. 290.

Jennings-Heywood Oil Syndicate No. 23; sec. 47; Arnaudet; drilled, fall, 1906; 2,500 barrels at first, then 1,200 barrels on air, November, 1906; abandoned, 1907; map No. 275.

Jennings-Heywood Oil Syndicate No. 25; sec. 47; Arnaudet; drilled, fall, 1906; twisted off and abandoned, spring, 1907; map No. 298.

Jennings-Heywood Oil Syndicate No. 26 (Gulf Refining Company No. 13); sec. 47; Arnaudet; drilled, fall, 1906; 300 barrels on air, December, 1906; producing, 1908; map No. 280.

Jennings-Heywood Oil Syndicate No. 27; sec. 47; Latreille; drilled, fall, 1906; 450 barrels, January, 1907; map No. 175. Fossils from 1,970 to 1,980 feet: *Rangia johnsoni*, *R. cuneata*, *Ostrea*, *Venus*.

Jennings-Heywood Oil Syndicate No. 28 (Gulf Refining Company No. 14); sec. 47; Arnaudet; drilled, spring, 1907; salt water; deepened, fall of 1908; map No. 276. Fossils collected by L. Reinecke and identified by C. J. Maury: *Rangia cuneata*, 800–1,100 feet; *Rangia johnsoni*, 1,710, 1,890–1,892 feet; *Ostrea*, common from 800 to 1,890 feet; *Mactra*, fragment of large species.

Jennings-Heywood Oil Syndicate No. 29; sec. 47; Arnaudet; drilled, January-March, 1907; blowout, etc.; map No. 289. Fossils collected by L. Reinecke and others and identified by C. J. Maury: *Rangia cuneata*, 200–400, 800–870, 1,540–1,560, 1,855, 1,920–1,940 feet; *Rangia johnsoni*, very abundant, 1,040–1,960 feet; *Ostrea*, 1,120–1,220, 1,240–1,300, 1,420–1,500, 1,540–1,560, 1,941–1,961 feet; *Mytilus*, 1,120–1,220, 1,420–1,500 feet; *Amnicola*, 1,540–1,560, 1,920–1,940, 1,960–1,980 feet; *Corbula contracta*, 1,920–1,940, 1,960–1,980 feet; *Mulinia quadricentennialis*, 1,941–1,961 feet; *Crassatellites* (young), 1,941–1,961 feet; *Cardium* (fragment), 1,941–1,961 feet; *Lucina crenulata*, 1,960–1,980 feet; *Arca campechensis*, 1,960–1,980 feet; *Natica emimulcides*?, 1,960–1,980 feet; *Balanus*, 1,840–1,920 feet; cypress wood, becoming carbonized, 300–400 feet; crinoid stems in gravel from Paleozoic, 740–760 feet.

Section of Jennings-Heywood Oil Syndicate's wells Nos. 29 and 29a.

[George Little, driller.]

	Thickness.	Depth.
	Feet.	*Feet.*
Upper beds not carefully measured	200	200
White and black quartz sand, becoming gravelly below 340 feet; calcareous and pyrite particles rare	240	440
Fine black and white quartz sand	50	490
Gravel, with pyrite; 3-foot layer of gumbo toward bottom	280	773
Gumbo	7	780
Fine green sand, with a few pebbles toward bottom	160	940
Blue shaly sand	60	1,000
Sand as in second bed above	20	1,020
Sandy blue clay	20	1,040
Blue clay, with some sand, pyrite, and plenty of shells	80	1,120
As above, harder	180	1,300
Fine green sand, with shells	140	1,440
Sandy clay, with shells; lower 20 feet with much pyrite	80	1,520
Plastic blue clay	20	1,540
Fine greenish-white sand with shells	20	1,560
Blue clay, with pyrite and shells	20	1,580
Fine greenish sand, with finely divided particles of pyrite and some shells	20	1,600
Sandy clay	20	1,620
Fine green sand; plenty of pyrite and a few shells; hard calcareous sandstone at 1,650 feet.	30	1,650
Derrick moved over 20 feet east; well No. 29a did not encounter the hard layer at 1,650 feet.		
Clay	30	1,680
Plastic blue clay, some sand and shells	100	1,780
Gumbo	20	1,800
Clay and sand as in second bed above; sand with pyrite, 1,820-1,840 feet; sand with pyrite and shells, 1,880-1,900 feet	120	1,920
Black and white sand, shells, and pyrite	40	1,960
Very fine white sand, shells, and pyrite	20	1,980

Jennings-Heywood Oil Syndicate No. 30; sec. 41; Syndicate Fee Simple; drilled, spring, 1907; salt water; map No. 146. Fossils collected by L. Reinecke, identified by C. J. Maury: *Natica* sp., 1,080–1,730 feet; *Unio* sp., 1,080–1,127, 1,403–1,483 feet; *Rangia cuneata*, 1,360–1,483, 1,527–1,611, 1,632–1,716, 1,840 feet; *Ostrea*, 1,840 feet; lignite, 1,277–1.362, 1,403–1,483 feet.

Section of Jennings-Heywood Oil Syndicate's well No. 30.

[Kid Connelly, driller.]

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	30	30
Sand and gravel	720	750
Gumbo	50	800
Sand, streaked with gumbo	280	1,080
Blue sandy clay, full of shells	47	1.127
Greenish-white sand, shells in upper 20 feet	42	1,169
Blue sand and gravel, with some shells	129	1,298
Sand, with clay and shells; shells in sand	62	1,360
Greenish sand, with limestone fragments	43	1,403
Sand, with limestone fragments and numerous shells	187	1,590
Blue clay, with some fine sand	5	1,595
Sand, as in second bed above	16	1,611

Jennings-Heywood Oil Syndicate No. 33; sec. 41; Syndicate Fee Simple; drilled, summer, 1907; salt water; map No. 148.

Jennings-Heywood Oil Syndicate No. 34 (Gulf Refining Company No. 34); sec. 47; Rex; drilled, summer, 1907; 2,500 barrels, June, 1907; produced, 1908; map No. 241.

Jennings-Heywood Oil Syndicate No. 35; sec. 47; Latreille; location only known; map No. 147.

Jennings-Heywood Oil Syndicate No. 38; sec. 41; Syndicate Fee Simple; drilled, summer, 1907; 200 barrels an hour at first, and then sanded up; location near that of map No. 159.

Jennings-Heywood Oil Syndicate No. 39; sec. 47; Latreille; location only known; map No. 173.

Jennings-Heywood Oil Syndicate No. 40; sec. 47; Rex; drilled, summer, 1907; 250 barrels, August, 1907; abandoned, 1908; map No. 255.

Jennings-Heywood Oil Syndicate No. 41 (Gulf Refining Company No. 19?); sec. 41; Syndicate Fee Simple; drilled, fall, 1907; abandoned, 1907; map No. 155.

Jennings-Heywood Oil Syndicate No. 44 (Gulf Refining Company No. 3); sec. 47; Rex; drilled, fall, 1907; 300 barrels, 1907; producing, November, 1908; map No. 240.

Jennings-Heywood Oil Syndicate No. 45; sec. 41; Syndicate Fee Simple; drilled, fall, 1907; 1,500 barrels; location close to that of map No. 153.

Jennings-Heywood Oil Syndicate No. 47; sec. 41; Syndicate Fee Simple; no data; location close to that of map No. 155.

Jennings-Heywood Oil Syndicate No. 57′; sec. 41; Syndicate Fee Simple; location near that of map No. 160.

Keoughan & Noble No. 1; sec. 46; Noble; completed, 1905; map No. 126.

Keoughan No. 2; sec. 46; Zeigler; producing, 1903; map No. 114.

Keoughan No. 3; sec. 46; Zeigler; producing, 1903–4; map No. 435.

Kneippe No. 1; sec. 47; Kneippe; drilled, January, 1905; 1,000 barrels; abandoned, 1906; map No. 249.

Kneippe No. 2; sec. 47; Kneippe; 3,000 barrels, March, 1905; map No. 244.

Laguerre No. 1; sec. 47; Kneippe; drilled, December, 1907; dry; map No. 242.

Lake No. 1; sec. 45; Schultz; drilled, 1903; said to have produced in 1903 and to have been drilled all in the daytime "so that the section could be well studied;" drilled by J. T. Newton (Oil Inv. Jour., September, 1903, p. 8); map No. 422.

Layne No. 1; sec. 45; Schultz; drilled, summer, 1903; map No. 394.

Layne Oil No. 2; sec. 45; Schultz; producing, 1904; deepened and dry, June, 1906; map No. 398.

Lovegrove & McIntosh No. 1; sec. 47; West Virginia; drilled, fall, 1904; 3,000-barrel gusher, December, 1904; 400 barrels, April, 1905; 500 barrels, June, 1905; 100 barrels, December, 1905; map No. 377. Gulf Refining Company No. 1 in same locality, producing, 1908.

Lyons No. 1; sec. 46; Evangeline; drilled, summer, 1903; producing, 1904; deepened, 1905; map No. 100.

Mahaffey No. 1; sec. 47; West Virginia; this well seems to be West Virginia No. 1 or "Virginia" of Bull. U. S. Geol. Survey No. 282; came in September, 1904, and sanded up after going "wild;" map No. 414.

McFarland Oil Company; sec. 45; Conklin; drilled before 1904; deepened by Higgins Oil and Fuel Company, 1906; map No. 440.

Mattison No. 1; sec. 47; Attakapas; drilled apparently late in 1907; map No. 271.

Mattison No. 2; Latreille, King tract; drilled, fall, 1907; dry.

Mattison No. 3; sec. 42; Mattison; drilled, spring, 1908; 500 barrels, March; not producing, November, 1908; map No. 26.

Mattison No. 3; sec. 45; drilled, February, 1908; nonproducing, November, 1908; map No. 12.

Mattison No. 4; sec. 42; drilled, spring, 1908; 300 barrels, March; nonproducing, November, 1908; map No. 27.

Mermentau Development Company No. 1; sec. 46; Zeigler; produced, 1903–4; map No. 135.

Mermentau Development Company No. 2; sec. 46; Jennings Fee Simple; drilled summer, 1903; produced spectacular blow out; nonproducing, 1908; map No. 89.

Mermentau Development Company No. 3; sec. 46; Jennings-Clement; probably drilled in 1903; deepened, summer, 1906; 75 barrels, 1906; map No. 88.

Mermentau Development Company No. 4; sec. 46; Jennings Fee Simple; drilled, 1904; deepened, 1906; abandoned, 1907; map No. 90.

Moonshine No. 1; sec. 47; Moonshine acre; 1,000 barrels on air, April, 1905; abandoned, October, 1905; map No. 267.

Morse Nos. 1 and 2. See Bass & Guffey No. 1; Bass No. 2.

Morse No. 3; sec. 46; Heywood; drilled, summer, 1903; producing, 1904, 1908; map No. 62.

Morse No. 4; sec. 46; Morse; drilled, summer, 1903; flowed above derrick, August, 1903; nonproducing, 1908; map No. 65.

Morse No. 5; sec. 46; Morse; drilled, summer, 1903; 500 barrels, 1903; nonproducing, 1908; map No. 64.

Morse Nos. 6 and 7. See Bass Nos. 6 and 7.

National Oil Company No. 1; sec. 45; Schultz; 3,000 barrels, April, 1908; map No. 21.

National Oil Company No. 2; sec. 45; Schultz; drilled, spring, 1908; 400 barrels, April; nonproducing, November, 1908; map No. 16.

National Oil Company No. 3; sec. 45; Schultz; drilled, spring, 1908; 300 barrels; map No. 22.

National Oil Company No. 4; sec. 45; Conklin; drilled, summer, 1908; 800 barrels; map No. 4.

National Oil Company No. 5; sec. 45; McFarlain; drilled, summer, 1908; 100 barrels, August, 1908; worked on, November, 1908; map No. 10.

National Oil Company No. 6; sec. 45; Conklin; drilled, fall, 1908; 150 barrels; map No. 2.

National Oil Company No. 7; sec. 45; Conklin; drilled, fall, 1908; salt water; map No. 1.

New Orleans-Jennings Mutual No. 1 (Producers-Evangeline No. 2); sec. 46; drilled, spring, 1905; 40 barrels daily; map No. 101.

Heywood (Noble) No. 1; sec. 46; Noble; drilled, spring, 1905; poor producer; map No. 117.

Noble No. 2; sec. 46; Noble; drilled, spring, 1907; abandoned, June, 1907; map No. 129.

Noble No. 2; sec. 42; Eunice-Crowley; drilled, January-February, 1908; 500 barrels, February, 1908; map No. 39.

Northern No. 1; sec. 46; Noble; drilled, fall, 1902; producing, 1903–4; map No. 125.

Northern No. 2; sec. 46; Noble; drilled, 1902; producing, 1903–4; map No. 127.

Northern No. 3; sec. 46; Noble; drilled, spring, 1903; producing, 1904; abandoned, 1907; map No. 116.

Northern No. 4; sec. 46; Syndicate-Clement; drilled, 1903; producing, 1903–4; map No. 138.

Pelican Oil Company No. 1; sec. 63; halfway from Jennings field to Jennings; drilled in 1902; dry; No. 3 of Bull. U. S. Geol. Survey No. 212. Mr. Reinecke obtained a log of this well to depth of 2,512 feet; the log does not differ greatly from the general run of logs of the Jennings field, but it is styled "doubtful" in Mr. Reinecke's notes.

Pelican No. 2; Mr. Reinecke obtained a log (which he styles "unreliable") of a well by this number with a depth of 400 feet; location not known to the writer.

Pelican No. 3; sec. 46; Producers-Evangeline; drilled, summer, 1903; sometimes styled Pelican No. 1; map No. 97.

Prairie Mamou No. 1; sec. 47; Latreille; one of the early wells of the field; on the "hill;" dry at a depth of more than 2,200 feet, the "sand" said to have been found at that depth; map No. 411.

Producers No. 1; sec. 47; Latreille; drilled, summer, 1904; 5,000 barrels, August, 1904; 1,850,000 barrels in 54 days; stopped flowing, April 20, 1905; producing, November, 1908; map No. 223. Fossils collected by L. Reinecke and identified by C. J. Maury: *Rangia cuneata*, 1,688–1,895 feet; *Cerithium?* sp., 1,688–1,695 feet; *Cerithium*, 1,800–1,860 feet; *Mulinia quadricentennialis*, 1,720–1,860 feet; *Mulinia* sp., 1,688–1,695 feet.

Section of Producers well, No. 1.

[From Charles Clayton, field manager.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	30	30	Rock	2	1,716
Sand	182	212	Rock and pyrite	18	1,734
Gumbo	583	795	Gumbo	17	1,751
Clay	58	853	Rock and pyrite	18	1,769
Sand	67	920	Gumbo	41	1,810
Gumbo	60	980	Sand, with oil indications	11	1,821
Sand	50	1,030	Gumbo	11	1,832
Gumbo	170	1,200	Soft shaly rock	6	1,838
Sand (slight oil showing)	50	1,250	Gumbo (6-inch casing set on this bed)	44	1,882
Gumbo	190	1,440	Sand, with oil and gas	88	1,970
Gumbo and bowlders	81	1,521	Gumbo.		
Gumbo	193	1,714			

Screen, 1,882–1,991 feet.

Producers No. 2; sec. 47; Latreille; hole only, November, 1908; map No. 227.

Producers Oil Company No. 1; sec. 46; Jennings-Clement; producing, 1903–4, 1905; map No. 162.

Section of Producers Oil Company's well No. 1, Jennings-Clement tract, sec. 46.

[Charles Dawson, driller.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Record to	....	1,735	Sand	21	1,912
Sand	10	1,745	Gas rock	2	1,914
Pyrite and clay	10	1,755	Clay and sand	5	1,919
Sand	65	1,820	Hard sand	16	1,935
Clay	30	1,850	Clay	12	1,947
Sand	8	1,858	Clay and bowlders	11	1,958
Clay	17	1,875	Sand and shells	60	2,018
Sand	13	1,888	Clay.		
Rock	3	1,891			

Screen, Layne, 102 feet.

Producers Oil Company No. 1; sec. 42; Eunice-Crowley; drilled, spring, 1908; salt water, April, 1908; map No. 47.

Producers Oil Company No. 1; sec. 46; Evangeline; abandoned location; map No. 101′.

Producers Oil Company No. 2; sec. 46; Jennings-Clement; producing, 1903–4; deepened, 1906; abandoned, 1908; map No. 83.

Producers Oil Company No. 1; sec. 42; Eunice-Crowley; drilled, spring, 1908; salt water, March, 1908; map No. 43.

Producers Oil Company No. 2; sec. 47; Producers half acre; drilled before 1907; map No. 362.

Producers Oil Company No. 3; sec. 46; Jennings-Clement; drilled, summer, 1903; wild well; finished without screen; blew carloads of sand; producing, 1903–4; deepened, 1906; map No. 434.

Producers Oil Company No. 3; sec. 47; Producers half acre; drilled before 1907; map No. 367.

Producers Oil Company No. 3; sec. 47; Latreille; deepened, June, 1905; map No. 226. Fossils collected: *Rangia cuneata*, 1,760–1,772 feet; *Mulinia*, 1,760–1,772, 1,925 feet; *Mulinia quadricentennialis*, 1,975 feet; *Ostrea*, 1,925–1,975 feet; *Cerithium*, 1,925 feet.

Producers Oil Company No. 4; sec. 46; Producers-Evangeline; drilled, summer, 1906; deepened; 200 barrels daily; map No. 96.

Section of Producers Oil Company's well No. 4, Producers-Evangeline tract, sec. 46.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	80	80	Bowlders and gumbo	11	1,750
Sand and gravel	710	790	Gumbo	30	1,780
Gumbo	35	825	Sand	6	1,786
Sand and gravel	211	1,036	Gumbo and bowlders	34	1,820
Gumbo	40	1,076	Shells	4	1,824
Shell	44	1,120	Shale	21	1,845
Gumbo	45	1,265	Pyrite and sand	15	1,860
Rock	8	1,273	Gumbo	12	1,872
Gumbo	77	1,350	Pyrite and sand	10	1,882
Hard shale and bowlders	70	1,420	Pyrite and gumbo	23	1,905
Gumbo and bowlders	110	1,530	Pyrite and sand	12	1,917
Pyrite	15	1,545	Sand	17	1,934
Gumbo	30	1,575	Gumbo	6	1,940
Sand and gravel	30	1,605	Shells	6	1,946
Gumbo	95	1,700	Gumbo	2	1,948
Gumbo and bowlders	37	1,737	Shale, shells, and sand	18	1,966
Rock	2	1,739			

Strainer, 1,816–1,966 feet.

Producers Oil Company No. 4; sec. 47; Latreille; drilled, fall, 1904; deepened, summer, 1905; map No. 445.

Producers Oil Company No. 4; sec. 47; Producers half acre; drilled before 1907; map No. 365.

Producers Oil Company No. 4; sec. 46; Jennings-Clement; drilled, spring, 1906; 600 barrels, April, 1906; producing, November, 1908; map No. 142.

Producers Oil Company No. 5; sec. 47; Producers half acre; drilled before 1907; map No. 372.

Producers Oil Company No. 5; sec. 46; Jennings-Clement; drilled, spring, 1906; salt water; deepened, 1906; abandoned, spring, 1907; map No. 143.

Section of Producers Oil Company's well No. 5, sec. 46.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	25	25	Sand	14	1,375
Sand	225	250	Gumbo	280	1,655
Gravel	277	527	Sand	15	1,670
Gumbo	5	532	Gumbo	59	1,729
Sand	6	538	Sand	16	1,745
Gravel	200	738	Gumbo	31	1,776
Gumbo	14	752	Sand	14	1,790
Gravel	72	824	Gumbo	25	1,815
Shell	4	828	Sand	17	1,832
Gumbo	37	865	Soft gumbo	18	1,850
Sand	40	905	Soft rock	5	1,855
Gumbo	159	1,064	Sand	53	1,908
Sand	21	1,085	Pyrite and sand	17	1,925
Gumbo	148	1,233	Rock	1	1,926
Sand	27	1,260	Sand	38	1,964
Gumbo	101	1,361			

Strainer, 4½-inch, 190 feet.

Producers Oil Company No. 5; sec. 47; Latreille; 6,500 barrels, May, 1906; not producing, November, 1908; map No. 222. From a depth of 1,800 feet the following forms occur: *Ostrea*, *Neritina* (like *picta*), *Cerithium*, and *Mulinia*.

Section of Producers Oil Company's well, No. 5, sec. 47.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	30	30	Rock	6	1,578
Sand	395	425	Sand	66	1,644
Sand and gravel	331	756	Gumbo	91	1,735
Gumbo	90	846	Gumbo and pyrite	20	1,755
Sand	180	1,026	Sand	35	1,790
Gumbo	38	1,064	Pyrite	2	1,792
Rock	5	1,069	Gumbo	38	1,830
Soft gumbo	221	1,290	Sand	12	1,842
Sand	30	1,320	Sand and pyrite	26	1,868
Gumbo	155	1,475	Gumbo	2	1,870
Gumbo and bowlders	79	1,554	Sand	67	1,937
Sand	18	1,572			

Strainer, 3-inch; 1,830-1,937 feet.

Producers Oil Company No. 6; sec. 46; Jennings-Clement; deepened, summer, 1906; salt water; abandoned, spring, 1907; map No. 144.

Producers Oil Company No. 6; sec. 47; Producers half acre; map No. 349.

Section of Producers Oil Company's well No. 6, Producers half-acre tract, sec. 47.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	14	14	Rock	3	1,644
Sand and gravel	696	710	Gumbo, rock below	9	1,653
Gumbo	30	740	Rock	4	1,657
Gravel	170	910	Clay	70	1,727
Clay	20	930	Pyrite	8	1,735
Marl	20	950	Clay	3	1,738
Gumbo	150	1,100	Sand	20	1,758
Clay and gumbo	67	1,167	Clay; 6-inch casing set at 1,770 feet	18	1,776
Pyrite and clay	165	1,332	Sand and shale	8	1,784
Sand and shale	9	1,341	Gumbo	24	1,808
Hard rock	3	1,344	Sand and shale	18	1,826
Clay	20	1,364	Sand	9	1,835
Sand and shale	36	1,400	Clay	11	1,846
Hard clay	50	1,450	Clay and pyrite	19	1,865
Clay and bowlders	129.5	1,579.5	Sand	60	1,925
Rock	10.5	1,590	Clay	5	1,930
Clay and pyrite	22	1,612	Sand	15	1,945
Rock (drilled on three days)	5	1,617			
Clay	24	1,641			

Screen, 4½-inch, 128 feet.

Producers Oil Company No. 6; sec. 47; Latreille; drilled, fall, 1905; salt water, January, 1906; deepened; not producing, 1908; map No. 178.

Section of Producers Oil Company's well No. 6, Latreille tract, sec. 47.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	35	35	Rock	2	1,497
Sand	35	70	Gumbo	153	1,650
Gumbo	30	100	Rock and shale	22	1,672
Sand and gravel	705	805	Gumbo	108	1,780
Gumbo	65	870	Rock and shells	8	1,788
Sand and gravel	152	1,022	Gumbo	6	1,794
Gumbo	58	1,070	Rock and shells	4	1,798
Shale	20	1,090	Pyrite and shells	32	1,830
Rock	1	1,091	Sand and shells	73	1,903
Shale	159	1,250	Fine sand	14	1,917
Gumbo	140	1,390	Sand	55	1,972
Rock	2	1,392	Sand and shells	10	1,982
Gumbo	103	1,495			

Screen, 4½-inch, 147 feet.

Producers Oil Company No. 7; sec. 47; Producers half acre; drilled before 1907; map No. 371.

Producers Oil Company No. 7; sec. 47; Latreille; derrick erected, 1906; drilling, 1907; abandoned, 1908; map No. 177.

Section of Producers Oil Company's well No. 7, Latreille tract, sec. 47.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	32	32	Gumbo	4	1,812
Sand	198	230	Hard shale	18	1,830
Gravel	230	460	Pyrite and rock	10	1,840
Gumbo	4	464	Gumbo	8	1,848
Gravel	211	675	Rock	1	1,849
Gumbo	31	706	Sand	4	1,853
Gravel	132	838	Gumbo	3	1,856
Gumbo	35	873	Sand	9	1,865
Sand	142	1,015	Pyrite and rock	22	1,887
Gumbo and shale	440	1,455	Sand	16	1,903
Gumbo	170	1,625	Pyrite	1	1,904
Rock	2	1,627	Gumbo	5	1,909
Gumbo	13	1,640	Sand	18	1,927
Rock	5	1,645	Gumbo	7	1,934
Gumbo	155	1,800	Sand	67	2,001
Pyrite	8	1,808			

Strainer, 1,938–2,001 feet.

Producers Oil Company No. 7; sec. 46; Clement; drilled, spring, 1907; 150 barrels; map No. 442.

Producers Oil Company No. 8; sec. 47; Latreille; drilled, spring, 1906; dry; deepened, fall, 1906; abandoned, 1908; map No. 229. Fossils: *Mulinia quadricentennialis*, *M.* cf. *mamouensis*, 1,990–2,012 feet.

Section of Producers Oil Company's well No. 8, Latreille tract, sec. 47.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	30	30	Gumbo	2	1,920
Sand	235	270	Pyrite and shells	44	1,964
Gravel	155	425	Pyrite and rock	16	1,980
Rock	2	427	Sand	5	1,985
Gumbo and bowlders	91	518	Pyrite	13	1,998
Rock	6	524	Blue shale	42	2,040
Gumbo and bowlders	144	668	Shells (loose)	6	2,046
Rock	3	671	Rock	1	2,047
Gumbo and bowlders	69	740	Shale	11	2,058
Gumbo	112	852	Gumbo	12	2,070
Sand	41	893	Pyrite and shells	15	2,085
Gumbo	19	912	Sand and pyrite	12	2,097
Sand	46	958	Gumbo and pyrite	30	2,127
Gumbo	57	1,015	Rock	1	2,128
Sand	30	1,045	Pyrite	8	2,136
Shale	96	1,141	Rock	3	2,139
Rock	5	1,146	Sand	20	2,159
Shale and bowlders	70	1,216	Rock and pyrite	2	2,161
Gumbo	77	1,293	Sand	5	2,166
Rock	2	1,295	Rock and pyrite	1	2,167
Gumbo	115	1,410	Sand	2	2,169
Shale	45	1,455	Rock	1	2,170
Gumbo and bowlders	65	1,500	Rock	3	2,173
Sand	120	1,640	Sand	6	2,179
Rock	3	1,643	Gumbo.		
Gumbo	47	1,690	Pipe sidetracked and well redrilled from 1,970 feet.		
Sand	30	1,720			
Pyrite	5	1,725	Sand	20	1,990
Gumbo	71	1,796	Pyrite	10	2,000
Sand	14	1,810	Shale	32	2,032
Rock	2	1,812	Shells	10	2,042
Gumbo	33	1,845	Rock	5	2,047
Rock and pyrite	10	1,855	Sand	13	2,060
Gumbo	20	1,875	Pyrite and sand	15	2,075
Rock and pyrite	15	1,890	Gumbo and pyrite	15	2,090
Gumbo	20	1,910	Sand	13	2,103
Pyrite with shells	6	1,916	Gumbo	17	2,120
Soft rock	2	1,918			

Producers Oil Company No. 8; sec. 47; Producers half acre; apparently drilled about 1906; map No. 347.

Section of Producers Oil Company's well No. 8, Producers half-acre tract, sec. 47.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	40	40	Rock	10	1,575
Sand	420	460	Clay	5	1,580
Sand and gravel	270	730	Rock	10	1,590
Clay	30	760	Clay	10	1,600
Shale	20	780	Pyrite and clay	15	1,615
Sand	205	985	Clay and bowlders	15	1,630
Clay	185	1,170	Clay	58	1,688
Clay and bowlders	50	1,220	Pyrite and sand	12	1,700
Clay	120	1,340	Clay	45	1,745
Clay and bowlders	84	1,424	Pyrite	3	1,748
Clay	16	1,440	Clay	20	1,768
Clay and bowlders	49	1,489	Sand	28	1,796
Rock	2	1,491	Clay	57	1,853
Gumbo	74	1,565			

Six-inch pipe set at 1,675 feet; blank pipe 150.5 feet long.

Producers Oil Company No. 9; sec. 47; Latreille; drilled, spring, 1906; salt water; deepened, 1,000 barrels, July, 1906; producing, 1908; map No. 225.

Section of Producers Oil Company's well No. 9.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	40	40	Sand	40	1,410
Sand	100	140	Gumbo	224	1,634
Gravel	723	863	Sand	52	1,686
Gumbo	10	873	Gumbo	59	1,745
Sand	27	900	Pyrite	27	1,772
Gumbo	340	1,240	Gumbo	20	1,792
Pyrite	5	1,245	Sand	126	1,918
Sand	30	1,275	Gumbo	20	1,938
Gumbo	95	1,370	Sand and shells	57	1,995

Strainer, 3-inch, 105 feet.

Producers Oil Company No. 10; sec. 47; Latreille; drilled and abandoned, fall, 1906; second drilling, June, 1907; 800 barrels; cleaning, November, 1908; map No. 171.

Section of Producers Oil Company's wells Nos. 10 and 10b.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	20	20	Rock	13	1,203
Sand	291	311	Sand	120	1,323
Clay	24	335	Gumbo	17	1,340
Gravel and bowlders	376	711	Shale	40	1,380
Gumbo	29	740	Shells and sand	77	1,457
Sand and gravel	135	875	Hard shale	23	1,480
Gumbo	61	936	Shells and sand	15	1,495
Sand	20	956	Sand	5	1,500
Shale	81	1,037	Rock	28	1,528
Shale and gumbo	58	1,095	No. 10b, derrick moved 30 feet west.		
Gumbo and bowlders	117	1,112			
Sand	12	1,124	Clay	12	12
Gumbo and bowlders	10	1,134	Sand	637	649
Shale	4	1,138	Gumbo	41	690
Sand	12	1,150	Sand	195	885
Rock	15	1,165	Gumbo	105	990
Sand	5	1,170	Gumbo and shale	95	1,085
Soft rock	3	1,173	Rock	2	1,087
Hard rock	13	1,186	Gumbo	38	1,125
Sand	4	1,190	Rock. Hole left incomplete.		

Producers Oil Company No. 11; sec. 47; Latreille; drilled, fall, 1907; 2,000 barrels, October, 1907; map No. 170.

Producers Oil Company No. 12; sec. 47; Latreille; drilled, June, 1907; 600 barrels, August, 1907; deepened, December, 1907; producing, 1908; map No. 172.

Producers Oil Company No. 13; sec. 47; Latreille; drilled, summer, 1907; 3,000 barrels, August; deepened, December, 1907; salt water, January, 1908; dead, November, 1908; map No. 168.

Producers Oil Company No. 14; sec. 47; Latreille; drilled, summer, 1907; deepened, September, 1907; 2,950 barrels, September, 1907; producing, November, 1908; map No. 219.

Producers Oil Company No. 15; sec. 47; Latreille; drilled, summer, 1907; 2,000 barrels, September, 1907; producing, 1908; map No. 220.

Producers Oil Company No. 16; sec. 47; Latreille; drilled, fall, 1907; 2,000 barrels, October, 1907; map No. 165.

Producers Oil Company No. 17; sec. 47; Latreille; drilled, fall, 1907; 2,000 barrels, October, 1907; map No. 167.

Producers Oil Company No. 19; sec. 47; Latreille; drilled, fall, 1907; 1,000 barrels, October, 1907; producing, 1908; map No. 214.

Producers Oil Company No. 20; sec. 47; Latreille; drilled, fall, 1907; gas at first, then 100 barrels oil, November, 1907; producing, 1908; map No. 215.

Producers Oil Company No. 21; sec. 47; Latreille; drilled, fall, 1907; abandoned, December, 1907; map No. 187.

Producers Oil Company No. 21; sec. 47; Latreille; drilled, spring, 1908; 4,000 barrels, June, producing, November, 1908; map No. 192.

Producers Oil Company No. 22; sec. 47; Latreille; drilled, fall, 1907; 1,500 barrels, November, 1907; not producing, November, 1908; map No. 166.

Producers Oil Company No. 23; sec. 47; Latreille; drilled, fall, 1907; 800 barrels, November, 1907; producing, November, 1908; map No. 221.

Producers Oil Company No. 24; sec. 47; Latreille; drilled, fall, 1907; 1,500 to 3,500 barrels, December, 1907; not producing, November, 1908; map No. 216.

Producers Oil Company No. 25; sec. 47; Latreille; drilled, fall, 1907; 150 barrels, December, 1907; producing, 1908; map No. 224.

Producers Oil Company No. 26; sec. 47; Latreille; drilled, December, 1907; 500 barrels, January, 1908; not producing, November, 1908; map No. 218.

Producers Oil Company No. 27; sec. 47; Latreille; drilled, fall, 1907; 1,200 barrels, December, 1907; producing, November, 1908; map No. 207.

Producers Oil Company No. 28; sec. 47; Latreille; drilled, December, 1907; 3,000 barrels, January, 1908; producing, November, 1908; map No. 205.

Producers Oil Company No. 29; sec. 47; Latreille; drilled, spring, 1908; abandoned, April, 1908; map No. 169.

Producers Oil Company No. 30; sec. 47; Latreille; drilled, January, 1908; 1,000 barrels, February; producing November, 1908; map No. 217.

Producers Oil Company No. 31; sec. 47; Latreille; drilled, spring, 1908; 3,000 barrels, May; not producing, November, 1908; map No. 198.

Producers Oil Company No. 32; sec. 47; Latreille; drilled, January, 1908; strong gas well, February; not producing, November, 1908; map No. 186.

Producers Oil Company No. 33; sec. 47; Latreille; drilled, January, 1908; 500 barrels, February; cleaning, November, 1908; map No. 210.

Producers Oil Company No. 34; sec. 47; Latreille; drilled, January-February, 1908; salt water, March, 1908; map No. 211.

Producers Oil Company No. 35; sec. 47; Latreille; drilled, spring, 1908; producing, November, 1908; map No. 212.

Producers Oil Company No. 36; sec. 47; Latreille; drilled, February, 1908; 2,500 barrels, March; producing, November, 1908; map No. 209.

Producers Oil Company No. 37; sec. 47; Latreille; drilled, spring, 1908; 500 barrels, April; producing November, 1908; map No. 208.

Producers Oil Company No. 39; sec. 47; Latreille; drilled, spring, 1908; not producing, November, 1908; map No. 206.

Producers Oil Company No. 40; sec. 47; Latreille; drilled, spring, 1908; 4,000 barrels, April, 1908; not producing, November, 1908; map No. 197.

Producers Oil Company No. 41; sec. 47; Latreille; drilled, spring, 1908; flowed at first at the rate of 4,800 barrels daily, then dropped to 4,000 barrels on air; producing, November, 1908; map No. 196.

Producers Oil Company No. 42; sec. 47; Latreille; drilled, spring, 1908; dry; deepened and produced 500 barrels, June, 1908; producing, November, 1908; map No. 203.

Producers Oil Company No. 43; sec. 47; Latreille; drilled, spring, 1908; 5,000 barrels, May; producing, November, 1908; map No. 195.

Producers Oil Company No. 44; sec. 47; Latreille; drilled, summer, 1908; 500 barrels, June, 1908; map No. 163.

Producers Oil Company No. 45; sec. 47; Latreille; drilled, spring, 1908; 3,000 barrels, June; producing, November, 1908; map No. 213.

Producers Oil Company No. 46; sec. 47; Latreille; drilled, summer, 1908; producing, November, 1908; map No. 179.

Producers Oil Company No. 47; sec. 47; Latreille; drilled, summer, 1908; 300 barrels, July; producing, November, 1908; map No. 176.

Producers Oil Company No. 48; sec. 47; Latreille; drilled, summer, 1908; salt water, July, 1908; map No. 193.

Producers Oil Company No. 49; sec. 47; Latreille; drilled, summer, 1908; 400 barrels, July; producing, November, 1908; map No. 199.

Producers Oil Company No. 50; sec. 47; Latreille Derrick; map No. 172.

Producers Oil Company No. 51; sec. 47; Latreille; drilled, summer, 1908; lost, fall, 1908; map No. 204.

Producers Oil Company No. 53; sec. 47; Latreille; drilled, summer, 1908; 300 barrels, July; producing, November, 1908; map No. 202.

Producers Oil Company No. 54; sec. 47; Latreille; drilled, summer, 1908; 1,000 barrels, August; producing, November, 1908; map No. 201.

Producers Oil Company No. 55; sec. 47; Latreille; drilled, summer, 1908; 1,000 barrels, August; producing, November, 1908; map No. 194.

Producers Oil Company No. 56; sec. 47; drilled, summer, 1908; 500 barrels, July; producing, November, 1908; map No. 183.

Producers Oil Company No. 57; sec. 47; Latreille; drilled, summer, 1908; 100 barrels, September; producing, November, 1908; map No. 200.

Producers Oil Company No. 58; sec. 47; Latreille; drilled, summer, 1908; 250 barrels, September; producing, November, 1908; map No. 188.

Producers Oil Company No. 59; sec. 47; Latreille; drilled, fall, 1908; 3,000 barrels, September, 1908; map No. 184.

Producers Oil Company No. 60; sec. 47; Latreille; drilled, fall, 1908; 400 barrels, October; producing, November, 1908; map No. 185.

Producers Oil Company No. 61; sec. 47; Latreille; drilled, fall, 1908; 200 barrels, October; producing, November, 1908; map No. 189.

Producers Oil Company No. 63; sec. 47; Latreille; drilled, fall, 1908; 400 barrels, November, 1908; not producing late in November; map No. 190.

Producers Oil Company No. 64; sec. 47; Latreille; drilled, fall, 1908; 2,000 barrels, November, 1908; map No. 180.

Producers Oil Company No. 65; sec. 47; Latreille; drilling, November, 1908; 900 barrels on air, December, map No. 181.

Producers Oil Company No. 66; sec. 47; Latreille; drilling, fall, 1908; map No. 191.

Producers Western No. 1; sec. 46; Producers-Evangeline; drilled, summer, 1908; producing, November, 1908; map No. 94.

Producers-Western; sec. 46; Producers-Evangeline; producing, 1908; map No. 95.

Rayne No. 1; a pumper, March, 1904. (See Rex No. 2.)

Rayne Planters No. 2; shown on map in Bull. U. S. Geol. Survey No. 282 on the site of Jennings-Heywood Oil Syndicate No. 11; map No. 239.

Rex; sec. 47; Rex; map No. 254.

Rex No. 1; sec. 47; Rex; drilled, spring, 1905; 4,000 barrels, May; 3,200 barrels, September; 2,500 barrels, November; producing, 1906; abandoned, 1908; map No. 253.

Rex No. 2; sec. 47; Rex; seems to be in the place of "Rayne Planters No. 1;" producing, 1904; deepened by the Rex people, 1905; long since abandoned; map No. 256.

Rex No. 3; sec. 47; Rex; abandoned producer; map No. 252.

Rex No. 4; sec. 47; Rex; located, July, 1907; abandoned; map No. 251.

Rowson and Haber No. 1; sec. 45; Schultz; old well drilled before 1904; map No. 402.

Savage No. 1 (Savage-Thompson-Savage Oil Syndicate); sec. 46; Jennings-Clement; brought in March 14, 1904; producing, 1904; map No. 432.

Savage-Morrical-Savage No. 1; sec. 46; Jennings Fee Simple; oil well drilled before 1904; map No. 93.

Schultz No. 1; sec. 45; Schultz; early well, drilled, before 1904; map No. 405.

Schultz No. 2; sec. 45; Schultz; early well, drilled, before 1904; map No. 399.

Schultz No. 2; sec. 47; Valée arpent; drilled, 1904–5; flowed 28,000 barrels from April 12 to April 30 and stopped; flowed 500 barrels, November, 1905; producing, 1908; map No. 263.

Schultz No. 2; sec. 47; Valée; producing, 1908; map No. 274.

Sharp & Benckenstein No. 1; sec. 47; Latreille; drilled, fall, 1906; salt water November, 1906; map No. 228.

Shippers Oil Company No. 1; sec. 46; Noble; drilled and operated, 1905–6; map No. 118.

Shippers Oil Company No. 2; sec. 47; Valée arpent; drilled, summer, 1906; 1,200–2,500 barrels, August, 1906; producing, 1908; map No. 262.

Shippers Oil Company No. 3; sec. 47; Kneippe; drilled, fall, 1906; salt water; map No. 248.

Shippers Oil Company No. 4; sec. 47; Valée arpent; drilled, spring, 1907; salt water; map No. 261. *Rangia cuneata* common, 1,240–1,493 feet.

Simons Oil Company No. 1; sec. 45; Conklin; dry in 1904; map No. 401.

Southern Oil Company, given as No. 10 on Hayes and Kennedy's map. According to Kennedy the oil sand was reached at a depth of 1,635 feet.

Southern Oil Company No. 1; 2 miles south of the field; given as No. 11 on Hayes and Kennedy's map. Oil sand said to occur at about 2,000 feet.

Southern No. 2; sec. 46; Syndicate-Clement; second well in the field; 4-inch; drilled, fall, 1901; producing, 1904; sand at 1,850 feet; reported as deepened to 1,950 feet in December, 1904; map No. 112.

Southern No. 3; sec. 46; Syndicate-Clement; drilled, summer, 1902; producing, 1903–4; map No. 119.

Southern No. 4; sec. 46; Syndicate-Clement; 4-inch, drilled by Charles Noble in fourteen days; producing, 1903–4; map No. 111.

Southern No. 5; sec. 46; Syndicate-Clement; producing, 1903–4; map No. 110.

Southern No. 6; sec. 46; Syndicate-Clement; drilled, spring, 1903; producing, 1904; map No. 113.

Southern No. 7; sec. 46; Syndicate-Clement; drilled, summer, 1903; producing, 1903–4; map No. 106.

Southern No. 8; sec. 46; Syndicate-Clement; drilled, summer, 1903; producing, 1903–1905; map No. 105.

Superior No. 1; sec. 45; Schultz; drilled, spring, 1903; producing, 1903; deepened, 1906; map No. 437.

Superior No. 2; sec. 45; Schultz; drilled, summer, 1903; producing, 1903–4; deepened by Longrove, 1906; map No. 439.

Superior No. 3; sec. 45; Schultz; drilled, summer, 1903; map No. 438.

Swift No. 1; sec. 46; Rowson & Haber; drilled, fall, 1903; dry; map No. 137.

Teche Development Company No. 1; sec. 47; Latreille; dry, February, 1907; abandoned, March, 1907; map No. 236. Fossils, collected by L. Reinecke and identified by C. J. Maury: *Rangia cuneata*, 876–1,158, 1,158–1,199, 1,322–1,363, 1,820–1,824, 1,954–1,997?, 2,040–2,074?, 2,084–2,106 feet; *Rangia johnsoni*, 1,322–1,363, 1,363–1,406, 1,406–1,489?, 1,820–1,824, 1,954–1,997, 1,997–2,074 feet; *Ostrea* (fragments, apparently *virginica*), 876–1,199, 1,322–1,406, 1,820–1,824, 1,954–1,997, 2,019–2,075, 2,084–2,106 feet; *Mulinia* cf. *quadricentennialis*, 158–1,199 feet; *Anachis obesa*, 1,158–1,199 feet; *Amnicola*, 1,363–1,406, 1,997–2,019 feet.

Section of Teche Development Company's well No. 1.

[W. O. Todd, driller.]

	Thickness.	Depth.
	Feet.	*Feet.*
Plastic bluish and yellowish clay	50	50
Yellowish to greenish sand, very fine at first but becoming coarser to a depth of 300 feet, then coarser with gravel	421	471
Blue plastic clay (gumbo)	26	497
Fine greenish sand, with numerous shells, especially between 522 and 544 feet, becoming a sandy clay	83	580
Gumbo	41	621
Blue sandy clay, with shell fragments	79	700
Gumbo	176	876
Plastic blue clay, with pebbles and shell fragments. A 3-foot rock at 1,085 feet, approximately	282	1,158
Blue clay, containing a large amount of sand and shells to 1,199 feet; less sand and shells below	311	1,469
Blue clay, little sand, many shell fragments to 1,575 feet; shells and sand disappearing below	186	1,655
Rock, probably limestone	3	1,658
Blue clay, shaly, with some shells and a little sand	127	1,785
Rock	5	1,790
Blue sandy shale, with shell fragments (with pieces of limestone, probably from above)	51	1,841
Not given, probably same as above	11	1,852
Blue shale and sand, latter full of pyrite	40	1,892
Blue sandy shale	62	1,954
Sand with shell fragments (and pyrite to 1,975 feet)	43	1,997
Blue shaly sand, with pyrite full of shells	22	2,019
Yellowish green sand with large amount of pyrite, with shells	59	2,078
Gumbo	7	2,085
Pyrite, broken limestone, and shells	21	2,106
Blue marl, with shell fragments	43	2,149
Hard, blue shale	16	2,165
Sandstone and pyrite	38	2,253
Blue shale	52	2,255
Sandstone and pyrite	14	2,269
Coarse, white sand	43	2,312

Records kept by L. Reinecke to 2,150 feet; that below taken from driller's notes.

Teche Development Company No. 2; sec. 47; Attakapas; drilled, summer, 1907; 1,500 barrels, October, 1907; producing, 1908; map No. 269.

Teche Development Company No. 2; sec. 47; Latreille; map No. 238.

Teeter No. 1; sec. 47; Arnaudet; drilled, summer, 1904; 4,000 barrels, March, 1905; 3,000, May; 50, September; abandoned, November, 1905; map No. 379.

Teeter No. 2; sec. 47; Arnaudet; drilled, fall, 1904; operating, 1905; map No. 381a.

Texas No. 1; sec. 47; Moonshine; producing, 1904; map No. 266.

Tierce No. 1; sec. 47; Arnaudet; drilled, summer, 1904; deepened, 1905; abandoned, 1906; map No. 335.

Tierce No. 2; sec. 47; Arnaudet; producing, 1904; deepened, 1906; map No. 329.

Tierce No. 3; sec. 47; Arnaudet; drilled, summer, 1904; came in blowing sand, wrecking derrick and then flowing oil, November, 1904; map No. 331.

Tierce No. 4; sec. 47; Arnaudet; drilled, fall, 1904; 6,000 barrels on air, April, 1905; map No. 332.

Tierce No. 5; sec. 47; Arnaudet; drilled, summer, 1905; 2,000 barrels, September, 1905; abandoned, December, 1907; map No. 328.

Tierce No. 6; sec. 47; Arnaudet; drilled, summer, 1905; 2,500 barrels, September; 2,500 barrels, November, 1905; map No. 330.

Tierce No. 7 (Jennings-Heywood Oil Syndicate No. 3; Gulf Refining Company No. 1); sec. 47; Arnaudet; derrick up, September, 1907; producing, 1908; map No. 333.

Union Oil and Development Company. So designated in Hayes and Kennedy's report (No. 12).

Undesignated well No. 2; sec. 46; Jennings-Clement; map No. 91.

Undesignated location, Valée arpent; map No. 265.

Western Oil Company No. 1; sec. 46; Producers-Evangeline; drilled, 1904: site of Producers No. 1; pumping, 1908; map No. 95.

West Virginia No. 1. See Mahaffey No. 1.

Wilkins No. 1; sec. 47; Wilkins; drilled, summer, 1904; 8,000 barrels, December; pumped, January, 1905; map No. 384.

Wilkins No. 2 (Gulf Refining Company No. 2); sec. 47; Valée arpent; drilled, fall, 1904; 20,000 barrels, November 20; stopped flowing, January 1, 1906; producing, 1908; map No. 259.

Wilkins No. 3; sec. 47; Wilkins; drilled, January-February, 1905; producing, 1905; deepened, 1906; producing, 1908; map No. 382.

Wilkins No. 4. See Gulf Refining Company No. 4; map No. 258.

Wilkins No. 5; sec. 47; Wilkins; drilled, spring, 1906; 5,000 barrels, April; producing, 1908; map No. 383.

Wilkins No. 6; sec. 47; Wilkins; drilled, fall, 1906; not producing, 1908; map No. 385.

Wood. See Crescent.

Zeigler No. 1; sec. 45; Schultz; not producing, 1908; map No. 17.

Zeigler No. 2; sec. 47; West Virginia (Gulf Refining Company No. 2); producing, 1906–1908; map No. 375.

Zeigler No. 2; sec. 45; Schultz; drilled, spring, 1908; 3,000 barrels, April; pumping, November, 1908; map No. 20.

Zeigler No. 3; sec. 45; Schultz; 400 barrels, March, 1907; map No. 404.

Zeigler No. 4; sec. 47; Valée; map No. 264.

Zeigler No. 3; sec. 45; Schultz; drilled, spring, 1908; 1,000 barrels, April; not producing, November, 1908; map No. 15.

Zeigler No. 5; sec. 45; Conklin; drilled, spring, 1908; 50 barrels (pumping), November, 1908; map No. 9.

Zeigler No. 5; sec. 47; West Virginia; producing on air, 1908; map No. 376.

Zeigler No. 6; sec. 47; West Virginia; drilled, fall, 1906; 400 barrels, November, 1906; map No. 374.

Zeigler No. 7 (Gulf Refining Company No. 4); sec. 47; West Virginia; drilled, spring, 1907; producing, November, 1908; map No. 373.

Zeigler No. 7 (Wheat and Wilson); sec. 45; Schultz; drilled, summer, 1908; 200 barrels, August; pumping, November, 1908; map No. 6.

Zeigler No. 8; sec. 45; Schultz; drilled, summer, 1908; 75 barrels, September; pumping, November, 1908; map No. 5.

Zeigler No. 9; sec. 45; Conklin; drilling, fall, 1908; map No. 3.

Explanation of map numbers (Pl. VIII).

1. National Oil Co. No. 7.
2. National Oil Co. No. 8.
3. Zeigler No. 9.
4. National Oil Co. No. 4.
5. Zeigler No. 8.
6. Zeigler No. 7.
7. Carencro No. 3.
8. Carencro No. 1.
9. Zeigler No. 5.
10. National No. 5.
11. Ismarie No. 3.
12. Mattison No. 3.
13. Interstate No. 2.
14. Ismarie No. 2.
15. Zeigler No. 3.
16. National No. 2.
17. Zeigler No. 1.
18. Interstate No. 1.
19. Heywood Bros. No. 1.
20. Zeigler No. 2.
21. National No. 1.
22. National Oil Co. No. 3.
23. Heywood-Acadia No. 4.
24. Mattison No. 6.
25. Heywood-Acadia No. 5.
26. Mattison No. 3.
27. Mattison No. 4.
28. Bass No. 1.
29. Heywood Eunice-Crowley No. 1.
30. Heywood Eunice-Crowley No. 3.
31. Heywood Eunice-Crowley No. 5.
32. Heywood Eunice-Crowley No. 4.
33. Heywood-Acadia.
34. Heywood-Acadia No. 6.
35. Heywood-Acadia No. 7.
36. Heywood-Acadia No. 1.
37. Heywood-Acadia No. 2.
38. Bass (T. H.) No. 2.
39. Noble Eunice-Crowley No. 2.
40. Heywood Eunice-Crowley No. 8.
41. Heywood Eunice-Crowley No. 9.
42. Heywood Eunice-Crowley No. 7.
43. Producers No. 2.
44. Gulf Refining Co. No. 3 (J. H. O. S. No. 55).
45. Gulf Refining Co. No. 2 (J. H. O. S. No. 51).
46. Heywood Eunice-Crowley No. 6.
47. Producers No. 1.
48. Gulf Refining Co. No. 1 (J. H. O. S. No. 48).
49. Gulf Refining Co. No. 4 (J. H. O. S. No. 59).
50. Gulf Refining Co. No. 5.
51. Gulf Refining Co. No. 6.
52. Gulf Refining Co. No. 23.

52′. Jennings-Heywood Oil Syndicate No. 47.

53. Gulf Refining Co. No. 13 (J. H. O. S. No. 50).
54. Gulf Refining Co. No. 14 (J. H. O. S. No. 53).
55. Gulf Refining Co. No. 24.
56. Gulf Refining Co.-Clement No. 1 (J. H. O. S. No. 56).
57. Gulf Refining Co.-Clement No. 2 (J. H. O. S. No. 57).
58. Gulf Refining Co.-Clement No. 4 (J. H. O. S. No. 62).
59. Gulf Refining Co.-Clement No. 3 (J. H. O. S. No. 61).
60. Gulf Refining Co.-Clement No. 7.
61. Gulf Refining Co.-Clement.
62. Morse No. 3.
63. Morse No. 1.
64. Morse No. 5.
65. Morse No. 4.
66. Gulf Refining Co. No. 5 (J. O. Co. No. 15).
67. Gulf Refining Co. No. 4 (J. O. Co. No. 14).
68. Gulf Refining Co.-Clement No. 8.
69. Gulf Refining Co. No. 3 (J. O. Co. No. 13).
70. Gulf Refining Co. No. 14.
71. Gulf Refining Co. No. 12.
72. Gulf Refining Co. No. 13.
73. Getty No. 1.
74. Chicago-Jennings No. 5.
75. Chicago-Jennings No. 6.
76. Gulf Refining Co. No. 11.
77. Jennings-Heywood-Clement No. 8.
78. Gulf Refining Co. No. 7.
79. Gulf Refining Co. No. 6.
80. Gulf Refining Co. No. 1.
81. Gulf Refining Co. No. 16.
82. Gulf Refining Co. No. 10.
83. Producers-Heywood No. 2.
84. Chicago-Jennings No. 7.
85. F. I. Getty (Ch.-Jen.) No. 8.
86. Chicago-Jennings No. 2.
87. Chicago-Jennings No. 11.

Explanation of map numbers (*Pl. VIII*)—Continued.

88. Mermentau.
89. Mermentau No. 2.
90. Mermentau No. 4.
91. Jennings Oil Co.
92. Jennings Oil Co. No. 12.
93. Savage-Morrical No. 11.
94. Producers-Evangeline No. 1.
95. Producers No. 1.
96. Producers-Evangeline No. 4.
97. Pelican No. 1.
98. Evangeline No. 5.
99. Evangeline No. 4.
100. Lyons No. 1.
101. Producers-Evangeline No. 2.
101′. An old abandoned Producers-Evangeline.
102. Gulf Refining Co. No. 15.
103. Heywood No. 2.
104. Heywood No. 3.
105. Southern No. 8.
106. Southern No. 7.
107. Heywood Oil Corporation No. 4.
108. Gulf Refining Co. No. 9.
109. Jennings Oil Co. No. 3.
110. Southern No. 5.
111. Southern No. 4.
112. Southern No. 2.
113. Southern No. 6.
114. Keoughan (?) No. 2.
114′. Gulf Refining Co. No. 8.
115. Keoughan-Midkiff No. 2.
116. Northern No. 3.
117. Heywood No. 1.
118. Shippers Oil Co. No. 1.
119. Southern No. 3.
120. Jennings-Clement No. 1.
121. Jennings-Clement No. 10.
122. Jennings-Clement No. 2.
123. Gulf Refining Co. No. 2 (in place of Jennings No. 9).
124. Jennings-Clement No. 4.
125. Northern No. 1.
126. Keoughan & Noble No. 1.
127. Northern No. 2.
128. Guffey Petroleum Co., Bass No. 18.
129. Noble No. 2.
130. Jennings-Heywood Oil Syndicate No. 2.
131. Crowley Petroleum Co. No. 1
132. Hill No. 5.
133. Guarantee No. 1.
134. C. D. Hill No. 4.
135. Mermentau No. 1.
136. Equitable No. 1.
137. Swift No. 1.
138. Northern No. 4.
139. C. D. Hill No. 3.
140. Crescent No. 1.
141. Jennings-Clement No. 5.
142. Producers-Jennings-Clement No. 4.
143. Producers-Jennings-Clement No. 5.
144. Producers-Jennings-Clement No. 6.
145. F. R. Jaenke No. 2.
146. Jennings-Heywood Oil Syndicate No. 30.
147. Gulf Refining Co. No. 25.
148. Jennings-Heywood Oil Syndicate No. 33.
149. Gulf Refining Co. No. 1 (J. H. O. S. No. 4).
150. Gulf Refining Co. No. 5 (J. H. O. S. No. 37).
151. Gulf Refining Co. No. 10 (J. H. O. S. No. 42).
152. Gulf Refining Co. No. 2 (J. H. O. S. No. 6(?)).
153. Gulf Refining Co. No. 20 (J. H. O. S. No. 45).
154. Gulf Refining Co. No. 26.
155. Gulf Refining Co. No. 19.
156. Gulf Refining Co. No. 21.
157. Gulf Refining Co. No. 17.
158. Gulf Refining Co. No. 22.
159. Gulf Refining Co. No. 15.
160. Gulf Refining Co. No. 16.
161. Gulf Refining Co. No. 18.
162. Producers No. 50.
163. Producers No. 44.
164. Producers No. 38.
165. Producers No. 16.
166. Producers No. 22.
167. Producers No. 17.
168. Producers No. 13.
169. Producers No. 29.
170. Producers No. 11.
171. Producers No. 10.
172. Producers No. 12.
173. Jennings-Heywood Oil Syndicate No. 39.
174. Jennings-Heywood Oil Syndicate No. 35.
175. Jennings-Heywood Oil Syndicate No. 27.
176. Producers No. 47.

Explanation of map numbers (*Pl. VIII*)—Continued.

177. Producers No. 7.
178. Producers No. 6.
179. Producers No. 46.
180. Producers No. 64.
181. Producers No. 65.
182. Producers No. 18.
183. Producers No. 56.
184. Producers No. 59.
185. Producers No. 60.
186. Producers No. 32.
187. Producers No. 21.
188. Producers No. 58.
189. Producers No. 61.
190. Producers No. 63.
191. Producers No. 66.
192. Producers No. 21.
193. Producers No. 48.
194. Producers No. 55.
195. Producers No. 43.
196. Producers No. 41.
197. Producers No. 40.
198. Producers No. 31.
199. Producers No. 49.
200. Producers No. 57.
201. Producers No. 54.
202. Producers No. 53.
203. Producers No. 42.
204. Producers No. 51.
205. Producers No. 28.
206. Producers No. 39.
207. Producers No. 27.
208. Producers No. 37.
209. Producers No. 36.
210. Producers No. 33.
211. Producers No. 34.
212. Producers No. 35.
213. Producers No. 45.
214. Producers No. 19.
215. Producers No. 20.
216. Producers No. 24.
217. Producers No. 30.
218. Producers No. 26.
219. Producers No. 14.
220. Producers No. 15.
221. Producers No. 23.
222. Producers No. 5.
223. Producers No. 1.
224. Producers No. 25.
225. Producers No. 9.
226. Producers No. 3.
227. Producers No. 2.
228. Sharp & Benckenstein No. 1.
229. Producers No. 8.
230. Benckenstein, Kaffrey & Martel No. 1.
231. Benckenstein, Kaffrey & Martel No. 2.
232. Benckenstein, Kaffrey & Martel No. 3.
233. Harfleigh No. 2.
234. Bass No. 1.
235. Bass No. 2.
236. Teche Oil Co. No. 1.
237. Crowley Oil and Mineral Co. No. 15.
238. Teche No. 2.
239. Gulf Refining Co. No. 2 (J. H. O. S. No. 11).
240. Gulf Refining Co. No. 3 (J. H. O. S. No. 44).
241. Gulf Refining Co. No. 34 (J. H. O. S. No. 34).
242. Leguerre (Kneippe) No. 1.
243. C. D. Hill No. 1.
244. Kneippe No. 2.
245. Caffery & Martel No. 1.
246. Attakapas No. 1.
247. Arlington No. 2.
248. Shippers No. 3.
249. Kneippe No. 1.
250. C. D. Hill No. 2.
251. Rex No. 4.
252. Rex No. 3.
253. Rex No. 1.
254. Rex (undesignated).
255. Jennings-Heywood Oil Syndicate No. 40.
256. Rex No. 2.
257. Jennings-Heywood Oil Syndicate No. 5 (G. R. Co. No. 1).
258. Gulf Refining Co. (Wilkins) No. 4.
259. Gulf Refining Co. (Wilkins) No. 2.
260. Harry (Valée) No. 1.
261. Shippers No. 4.
262. Shippers No. 2.
263. Schultz No. 2.
264. Valée No. 3.
265. Valée (undesignated).
266. Texas (Moonshine) No. 1.
267. Moonshine No. 1.
268. Arlington (Attakapas) No. 1.
269. Teche Nos. 1 or 2.
270. Harfleigh No. 3.
271. Mattison No. 1.
272. Attakapas No. 1.

Explanation of map numbers (*Pl. VIII*)—Continued.

273. Harfleigh No. 1 (near J. H. O. S. No. 20).
274. Schultz No. 1.
275. Arnaudet No. 23.
276. Gulf Refining Co. (Arnaudet) No. 14.
277. Crusell et al. No. 1.
278. Crusell & Bass No. 1.
279. Crusell No. 2.
280. Gulf Refining Co. (Arnaudet) No. 13.
281. Evangeline No. 7.
282. Teter No. 1.
283. Evangeline No. 3.
284. Evangeline No. 6.
285. Evangeline No. 2.
286. Evangeline No. 8.
287. Evangeline No. 3.
288. Evangeline No. 1.
289. Jennings-Heywood Oil Syndicate No. 29.
290. Jennings-Heywood Oil Syndicate No. 22.
291. Jennings-Heywood Oil Syndicate No. 36.
292. Jennings-Heywood Oil Syndicate No. 14 (G. R. Co. No. 6).
293. Gulf Refining Co. No. 18 (J. H. O. S. No. 42).
294. Gulf Refining Co. No. 7 (J. H. O. S. No. 15).
295. Gulf Refining Co. No. 12.
296. Gulf Refining Co. No. 15 (J. H. O. S. No. 31).
297. Gulf Refining Co. No. 16.
298. Jennings-Heywood Oil Syndicate No. 25.
299. Gulf Refining Co. No. 19 (J. H. O. S. No. 43).
300. Jennings-Heywood Oil Syndicate No. 8.
301. Gulf Refining Co. No. 2 (J. H. O. S. No. 7).
302. Heywood Oil Co. No. 2.
303. Heywood Oil Co. No. 9.
304. Crowley Oil and Mineral Co. No. 39.
305. Crowley Oil and Mineral Co. No. 38.
306. Crowley Oil and Mineral Co. No. 37.
307. Heywood No. 10.
308. Heywood No. 6.
309. Heywood No. 8.
310. Heywood No. 9.
311. Heywood No. 20.
312. Heywood No. 3.
313. Heywood No. 7.
314. Heywood No. 5.
315. Crowley Oil and Mineral Co. No. 24.
316. Crowley Oil and Mineral Co. No. 25
317. Crowley Oil and Mineral Co. No. 13.
318. Crowley Oil and Mineral Co. No. 17
319. Crowley Oil and Mineral Co. No. 26.
319′. Crowley Oil and Mineral Co. No. 18.
320. Crowley Oil and Mineral Co.
321. Crowley Oil and Mineral Co. No. 28.
322. Heywood No. 4.
323. Crowley Oil and Mineral Co. No. 35.
324. Crowley Oil and Mineral Co. No. 36.
325. Crowley Oil and Mineral Co. No. 11.
326. Gulf Refining Co. No. 4 (J. H. O. S. No. 12).
327. Gulf Refining Co. No. 5 (J. H. O. S. No. 13).
328. Tierce No. 5.
329. Tierce No. 2.
330. Tierce No. 6.
331. Tierce No. 3.
332. Tierce No. —.
333. Gulf Refining Co. No. 1 (J. H. O. S. No. 3; Tierce No. 7).
334. Gulf Refining Co. No. 9 (J. H. O. S. No. 17).
335. Tierce No. 1.
336. Gulf Refining Co. No. 3 (J. H. O. S. No. 13).
337. Crowley Oil and Mineral Co. No. 3.
338. Crowley Oil and Mineral Co. No. 10.
339. Crowley Oil and Mineral Co. No. 30.
340. Crowley Oil and Mineral Co. No. 31.
341. Crowley Oil and Mineral Co. No. 22.
342. Crowley Oil and Mineral Co. No. 12.
343. Crowley Oil and Mineral Co. No. 21.
344. Crowley Oil and Mineral Co. No. 33.
345. Crowley Oil and Mineral Co. No. 32.
346. Crowley Oil and Mineral Co. No. 2.
347. Producers No. 8.
348. Home No. 1.
349. Producers No. 6.
350. Bass No. 2.
351. Bass No. 10.
352. Crowley Oil and Mineral Co. No. 7.
352′. Crowley Oil and Mineral Co. No. 7′.
353. Crowley Oil and Mineral Co. No. 8.
354. Crowley Oil and Mineral Co. No. 1.
355. Bass No. 12.
356. Bass & Guffey No. 19.
357. Bass & Guffey No. 1.

Explanation of map numbers (Pl. VIII)—Continued.

358. Gulf Refining Co. (Bass) No. 16.
359. Gulf Refining Co. (Bass) No. 20.
359′. Bass No. 17.
360. Bass No. 18.
361. Bienville (Home) No. 2.
362. Producers No. 2.
363. Bass No. 9.
364. Bass (Morse) No. 8.
365. Producers No. 4.
366. Bass (Home) No. 11.
367. Producers No. 3.
368. Bass (Morse) No. 7.
369. Bass (Morse) No. 14.
370. Heywood & Chaddock No. 1.
371. Producers No. 7.
372. Producers No. 5.
373. Gulf Refining Co. No. 4 (Zeigler No. 7; W. Va.).
374. Zeigler (W. Va.) No. 6.
375. Zeigler (W. Va.) (G. R. Co.) No. 2.
376. Zeigler (W. Va.) No. 3 (G. R. Co. No. 3).
377. Longrove & McIntosh No. 1.
378. Gulf Refining Co. No. 11 (J. H. O. S. No. 20).
379. Teter (G. R. Co.) No. 1.
380. Jennings-Heywood Oil Syndicate (Arnaudet) No. 19.
381. Jennings-Heywood Oil Syndicate (Arnaudet) No. 18.
381′. Teter.
382. Wilkins No. 3.
383. Wilkins No. 5.
384. Wilkins No. 1.
385. Wilkins No. 6.
386. Bass (Morse) No. 6.
387. Gulf Refining Co. No. 15.
388. Heywood No. 6.
389. Heywood No. 0.
390. Heywood No. 3.
391. Heywood No. 4.
392. Heywood No. 2.
393. Heywood No. 5.
394. Layne No. 1.
395. Duson & Lyons No. 1.
396. Duson No. 2.
397. Duson No. 3.
398. Layne Oil Co. No. 2.
399. Shultz No. 2.
400. Home Oil Co. No. 1.
401. Simons Oil Co. No. 1.
402. Rowson & Haber No. 1.
403. Hill.
404. Zeigler No. 3.
405. Schultz No. 1.
406. Chicago-Jennings No. 9.
407. Chicago-Jennings No. 10.
408. Chicago-Jennings No. 3.
409. Charleston No. 1.
410. Crowley Oil and Mineral Co. No. 23.
411. Prairie Mamou No. 1.
412. Crowley Oil and Mineral Co. No. 5.
413. Heywood Oil Corporation No. 1.
414. Mahaffey (W. Va.).
415. Bass (Home) No. 13.
416. Crowley Oil and Mineral Co. No. 4.
417. Crowley Oil and Mineral Co. No. 6.
418. Crowley Oil and Mineral Co. No. 14.
419. Crowley Oil and Mineral Co. No. 19.
420. Crowley Oil and Mineral Co.
421. Crowley Oil and Mineral Co. No. 27.
422. Lake No. 1.
423. Ismerie (Duson, Lyons & Co.).
424. Heywood Oil Co.
425. Crowley Oil Co. No. 9.
426. Jennings (Clement) No. 11 (close to G. R. Co. No. 10).
427. Jennings-Heywood Oil Syndicate No. 45 (close to No. 153).
428. Jennings-Heywood Oil Syndicate No. 47′ (close to No. 155).
429. Jennings-Heywood Oil Syndicate No. 38.
430. Jennings-Heywood Oil Syndicate No. 51′.
431. Bienville No. 1.
432. Savage No. 1 (site of J. H. O. S. No. 7).
433. Chicago-Jennings No. 4.
434. Producers No. 1.
435. Keoughan (Zeigler) No. 3.
436. American Oil Co. No. 1.
437. Superior (Schultz) No. 1.
438. Superior (Schultz) No. 3.
439. Superior No. 2.
440. McFarlain Oil Co.
441. Carencro No. 2.
442. Producers (Clement) No. 7.
443. Jennings-Heywood Oil Syndicate No. 21.
444. Jennings-Heywood Oil Syndicate No. 16.
445. Producers (Latreille) No. 4.

PINE PRAIRIE.

Location and topography.—A few limestone outcrops in northwestern St. Landry Parish, near Bayou Chicot, have long been known to geologists; and the limestone has often been referred to as the Bayou Chicot or St. Landry marble deposit. To the northeast of the small stream traversing the area open prairie prevails, with gentle slopes or slight undulations. To the south the slopes are abrupt.

History and development.—The limestone at this place furnished material for several rude kilns even before the war, but until recently very little has been done toward investigating this locality. In the last few years a sufficient amount of prospecting with hand tools has been done to prove that within 100 feet of the surface the limestone masses are very irregular and could not be regarded as offering great inducements for limestone quarrying, at least while no railroad was within 10 miles of the place. The advent of the Rock Island road within about 2 miles of the quarries, with a station at Pine Prairie, changed the situation somewhat, and the Myles Mineral Company has for the past year been systematically exploiting the area. Two wells reaching depths of more than 500 feet and about a dozen shallow test holes are sufficient to show something of the geology of the area and to give some hints as to its financial possibilities.

Geology.—The two important outcrops in quarries of the limestone rocks referred to are shown on Plate XXX of the Louisiana Geological Survey's Bulletin No. 7. These rocks consist of the whitish-blue, crystalline, cavernous material so characteristic of saline-dome areas, notably west of Winnfield at the surface, or in many of the oil fields at various depths. It is unfossiliferous and evidently of secondary origin, but is very pure. In the lower quarry, near the bayou, small black specks are seen in the light limestone, and these when heated smoke and give a strong asphalt or petroleum odor. Deep well No. 2 is but a few hundred feet northwest of this outcrop and showed, according to Mr. Journée, of the Myles Mineral Company, a log in outline as follows:

Log of deep well No. 2, near Pine Prairie.

	Thickness.	Depth.
	Feet.	*Feet.*
Unconsolidated material	102	102
Bowlder	3	105
Blue gumbo and shale	150	255
Solid rock; good oil prospect at 400 feet; sulphur abundant	255	510
Salt.		

The first deep well was put down on the hill above the upper quarry and showed, according to Mr. Journée, the features following.

Log of deep well No. 1, near Pine Prairie.

	Thickness.	Depth.
	Feet.	*Feet.*
Sand and clay	80	80
Blue gumbo, showing oil and gas	6	86
Sand and clay	18	104
Porous rock, showing oil and gas	30	134
Very hard rock, dry	10	144
Porous or broken rock, showing oil and gas	2	146
Hard, dry, flinty rock	20	166
Porous rock, crevices filled with water sand	100	266
Nearly continuously in rock to salt; sulphur water abundant, 400-420 feet; oil showing abundant and continuous, 420-505 feet; last 75 feet showed much oil, but in rather dense rock	254	520
Salt.		

The shallow wells on the hill and in the flats suffice to prove the secondary, concretionary nature of the limestone in this vicinity, for although rock is found in many test holes at less than 20 feet from the surface, in others depths of 50 feet or more are required to attain consolidated materials. The so-called bedding planes shown in the outcrops at the quarries have probably not been formed by the usual method of deposition. They are merely the traces of the shells of different materials in the concretionary structure. The folds and high dips in the limestone have consequently no bearing on the structural features of the region in general.

Economic products.—The concretionary or secondary growth of the crystalline materials of this vicinity is clearly evident. Where oil or gas has been found in paying quantities in crystalline calcareous rock in such dome structures it has usually been found at greater depths than those at which rock salt has been reached here. The thickness of capping in this area may be scarcely sufficient for the retention of oil and the lack of gas pressure indicates the same thing. Oil and gas may and probably will be found, however, in pockets at the sides of the salt mass or masses, as explained on page 11.

Because of the occurrence of salt but 500 feet below the surface, beneath a capping of solid rock, so that mining could be advantageously carried on; the occurrence near and at the surface of pure calcium carbonate, which suggests the manufacture of soda ash; and the presence of sulphur to the extent, according to Mr. Journée, of 1½ per cent of the rock mass in places, which suggests the possibility of finding other and thicker deposits of purer sulphur, the region is one that deserves careful and thorough investigation.

SULPHUR MINE.

Location.—Sulphur is extracted in large quantities under the Frasch process by the Union Sulphur Company at a point about 3 miles west of Sulphur City, on the Southern Pacific Railroad, or about 15 miles west of Lake Charles, Calcasieu Parish.

History and general geology.—The first authentic geologic information concerning this vicinity is contained in the report of Hilgard's thirty-day reconnaissance in western Louisiana in 1868.[a] He reported the boring of two artesian wells "on two small islands in the (fresh water) marsh which forms the head of the Bayou Choupique," a small tributary of Calcasieu River. One, being sunk by the Louisiana Petroleum Company, had reached a depth of 1,230 feet, and another, by Dr. Kirkman, 450 feet. The sections of these wells and Hilgard's interpretations are herewith republished. The assignments under the head of "Formations" are decidedly different from those that would now be given to the several parts of the sections; but the fact that such geologic data as are here given were gathered at so early a date under most trying circumstances does great credit to Hilgard, the father of Gulf coast geology.

Profile of artesian wells, West Fork of Calcasieu River.[b]

Kirkman's well.			Louisiana Oil Co.'s well.			
Depth.	Thickness.	Materials.	Depth.	Thickness.	Materials.	Formations.
Feet.	*Feet.*		*Feet.*	*Feet.*		
354	354	Blue and yellow clay; some sand strata.	160	160	Blue clay, sometimes with layers of sand soaked with petroleum.	Port Hudson group.
446	92	Sand, with clay laminæ, 36 feet. Sand and gravel, 56 feet.	333	173	Loose sand and gravel; 138 to 153 feet very pebbly; 153 to 173 feet finer material.	Orange Sand group.
450	4	Sandy pipe clay.	343	10	Gray laminated clay ("soapstone").	Vicksburg group.
			383	40	Blue, sandy, nodular limestone, with marine shells, petroleum, and gas.	
			443	60	Soft white crystalline crumbling limestone; tube driven through.	Cretaceous formation.
			543	100	Pure crystalline sulphur.	
			690	147	Sulphur and gypsum; alternating; about one-third sulphur. 5-foot sulphur bed at 650 feet; 10-15-foot bed at 680 feet.	
			1,230	540	Pure gypsum, dense, granular, and coarsely crystalline, grayish or white.	

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[a] Hilgard, E. W., Am. Jour. Sci., 2d ser., vol. 48, 1869, pp. 331-346.

[b] Idem, p. 344.

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Small quantities of oil were found in the Louisiana Oil Company's well at a depth of 380 feet, but its slight value in comparison with the great sulphur deposits was at once recognized.

An expensive and disastrous attempt was made under Gen. Jules Brady to reach this sulphur deposit by sinking an iron caisson through the gravel and quicksand, which are more than 400 feet thick. Huge tubular sections were brought by water from France, unloaded on the west bank of Calcasieu River below Lake Charles, in part hauled by ox teams to the "mine," in part left on the river's bank for years, till they were obtained by the Myles Salt Company for casing its salt shaft on Weeks Island. In sinking this caisson to a depth of 110 feet several miners were overcome by poisonous gases and finally the undertaking was abandoned.

About 1892 the Diamond Prospecting Company made a very careful diamond-drill test of this locality, which showed that there is a far more frequent alternation of gypsum and sulphur beds than Hilgard's section seemed to indicate.[a] However, the latter closely resembles the sections[b] furnished to W. W. Clendenin, state geologist of Louisiana in 1894–95, by J. C. Hoffman, superintendent of the works. They read as follows:

Section of present working hole at sulphur mine near Sulphur City, La.

	Feet.
Clay, sand, and gravel	300
Shelly (bastard) limestone	80–100
Solid limestone	6– 7
Sulphur	110
Soft white rock	200

Section of bore hole at sulphur mine.

	Thickness.	Depth.
	Feet.	*Feet.*
Yellow and blue clay	80	80
Sandy blue clay	55	135
Almost pure clay with many sand pockets	30	165
Fine gray sand, water-bearing	135	300
Coarse gravelly sand	45	345
Coarse gray sand	10	355
Marl (oil and tar)	2½	357½
Blue sandy limestone	30½	388
Calcareous marl	4	392
Hard, rough gray calcareous marl	5	397
White saccharoidal calcareous marl	10	407
Same, reduced to sand	7	414
Hard, compact limestone	25	439
Sulphur	112	551

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[a] Bull. U. S. Geol. Survey No. 212, 1903, p. 134.

[b] Geol. and Agr. Louisiana, pt. 3, 1896, p. 345.

The writer's section, gathered from samples taken from a boring at the "mine," is as follows:

Section at sulphur mine.[a]

		Thickness.	Depth.
		Feet.	*Feet.*
1	Dirt and sand	25	25
2	Clay and sand	175	200
3	Quicksand	181-190	380-390
4	Gravel	25-60	410-450±
5	Broken rock and limestone	40	490
6	"Pepper and salt" sands with sulphur crystals	10	500
7	The same, more sulphur	2	502
8	Fine, whitish, black-specked sandy layers with grains of sulphur	3	505
9	Sulphur and gypsum	3	508
10	Same as No. 8	3	511
11	Sulphur and gypsum	3	514
12	Soft sandy clay and sulphur	6	520
13	Light-gray fine material and sulphur	6	526
14	The same, more coarsely crystalline	4	530
15	Same as No. 12	10	546
16	Coarse dark-gray gypsum and crystalline sulphur	3	536
17	Same as No. 12	10	540
18	Nearly pure sulphur with some gypsum	22	568
19	Crystalline sulphur and gypsum	8	576
20	Whitish, soft (clay?)	4	580
21	Sulphur and some gypsum	14	594
22	Same as No. 20	3	597
23	Sulphur and gypsum	7	604

[a] Rept. Louisiana Geol. Survey for 1902, p. 272.

Structure.—A dome structure in the underlying beds at this locality has been affirmed by Veatch[a] and by Hayes and Kennedy.[b]

Oil and gas.—Mention has already been made of oil in the original Louisiana Oil Company's well at 380 feet. In the Hoffman section given above "oil and tar" are noted at 357 feet. One well is said to have gushed oil 65 feet into the air. In 1900 a thick black tar-like oil, said to be an excellent lubricating oil, would flow slowly from a well when the valve was opened.

A special report to the Oil Investors' Journal, January 18, 1905, reads:

> Investigation brought out the fact that a flow of very heavy oil had been struck at a depth of about 600 feet. The oil came out of the 10-inch casing with the water and showed up in considerable quantity. No attempt was made to finish a well in the oil sand, the object of drilling being to get the sulphur. * * * A sample of the oil was tested at a Beaumont refinery and it was found to be 17° gravity, Baumé; flash point 270.

Poisonous gas has been referred to in connection with the attempt to sink a caisson at the mine. The existence of gas pressure is apparent from the fact that some of the small quantities of oil found here flow or gush. In various test holes a few miles from the mine considerable gas has been encountered. (See p. 24.)

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[a] Rept. Louisiana Geol. Survey for 1902, p. 98.

[b] Bull. U. S. Geol. Survey No. 212, 1903, p. 134.

One factor, perhaps the chief one, in the success of sulphur mining in Calcasieu Parish has been the cheap oil, first from Beaumont and afterward from Jennings. The writer is not aware that any attempt has been made to utilize to any considerable extent the oil on the holdings of the Union Sulphur Company.

VINTON.

Location and geographic features.—The exact location of the Vinton dome may be seen by consulting figure 9. It is about 3 miles southwest of Vinton station, on the Southern Pacific Railroad, in Calcasieu Parish. The sink or depression in the dome, now occupied by a shallow lake, is a noteworthy feature. As seen from a distance this is one of the most prominent domes along the Gulf coast. It rises conspicuously above the coastal prairie lands and its form is certainly suggestive of unusual structural and topographic features for this region.

History and general geology.—Early in the days of the great excitement at Spindletop, which lies but a short distance to the west, this dome, on account of its size and form and its gas and "sour" water seepages, was regarded as a most likely locality for finding oil in immense quantities. It is rumored that Mr. Vincent's holdings of several thousand acres in this vicinity were actually bargained for at a rate of $300 an acre. The transaction, however, was never completed.

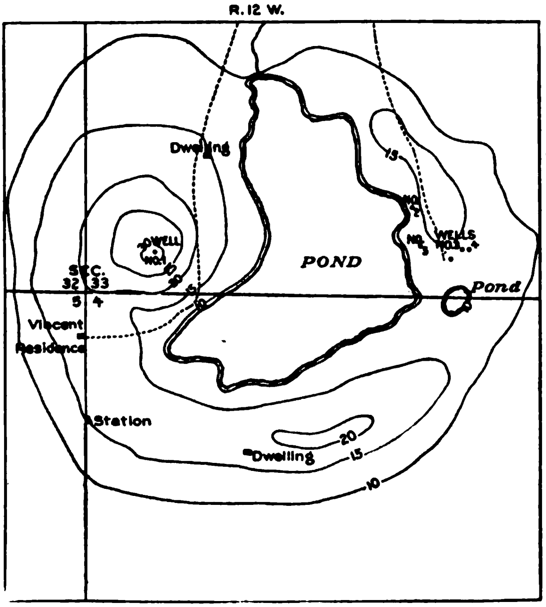

FIGURE 9.—Map of the Vinton dome, Calcasieu Parish.

W. B. Sharp and Ed. Prather drilled on this dome in 1902, and oil was reported from the same region in that year at a depth of 280 feet. The T. C. Stribling well, also of early date, was noted by Hayes and Kennedy,[a] who reported that a depth of 1,000 feet was said to have been reached, though the log was complete to 454 feet only, and who mentioned the characteristic features of this locality—

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[a] Bull. U. S. Geol. Survey No. 212, 1903, p. 135.

a heavy bed of very coarse gravel between 400 and 500 feet, almost impossible of penetration with the rotary drill; a strong artesian flow of black sulphur water from this gravel; and oil very near the surface, beneath the 20-foot stratum of surface clay.

Fenneman[a] notes six attempts in 1902 to 1904, inclusive, to penetrate the bowlder or gravel bed; three were successful, attaining depths of 1,100 to 1,200 feet. He observed the occurrence of gypsum and native sulphur crystals, but failed to obtain a complete and characteristic log of any well in the region. The following log of the Vinton Oil and Sulphur Company's well No. 2 was obtained through the courtesy of Mr. Vincent and of Mr. O. W. Myers, who was in charge of the drilling.

Log of Vinton Oil and Sulphur Company's well No. 2.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and sand	60	60
Joint clay	5	65
Sand, oil-showing	7	72
Wood, oil-showing	3	75
Sand	15	90
Tough clay	11	101
Sand	22	123
Blue tough clay	13	136
Sand, good showing of oil	14	150
Tough clay	15	165
Oil sand (and gas)	7	172
Tough clay	4	176
Tough clay, oil showing	6	182
Tough clay	5	187
Wood and oil	3	190
Tough clay	14	204
Wood (little oil)	2	206
Sand rock, soft	59	265
Gravel	4	269
Porous sand	37	306
Gravel	39	345
Porous sand	15	360
Gravel	15	375
Rock layer, with gravel	6	381
Gravel	6	387
Rock and gravel	9	396
Rock; gravel present	7	403
Hard conglomerate	12	415
Black gravel and sulphur	58	473
Hard white rock	2	475
Hard sand rock	30	505
Hard white rock	36	541
Rock with sulphur	2	543
White rock	138	681
Sand rock; water and gas	9	690
Hard white rock; showing of sulphur	65	755
Very hard rock	20	775
Softer rock, with showing of sulphur	7	782
Soft sand rock	40	822
Hard sand rock and white rock	35	857
White rock	18	875
Hard white rock	11	886
White rock with sulphur	12	898
Hard rock	38	936
Sand with sulphur	4	940
Soft sand (?) rock	60	1,000
Hard rock (anhydrite)	16	1,016

Specimens seen at the well indicate that a large amount of the "rock" is crystalline anhydrite. The sulphur, water, and gas first appeared in this well at 580 feet. One serious difficulty encountered, besides the conglomerate layer already mentioned, is due to the cavernous character of the rock layers. For days, in spite of filling in with quantities of mud, there is no "return."

In 1907, Wilkins, Zeigler & Rowson started a test hole on the Caffal farm, adjoining the Vincent tract, but after reaching a depth of 700 feet abandoned the enterprise and moved to Anse la Butte.[b]

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[a] Bull. U. S. Geol. Survey No. 282, 1906, p. 110.

[b] Oil Inv. Jour., November 5, 1907.

Oil and gas.—In various shallow wells east of the large pond shown in figure 9 oil of a very dark, heavy appearance can be obtained by hand pumps. Eighteen or 20 such wells yield 15 gallons of oil daily, and it is used as lubricating oil by the surrounding farmers. Such gas as has been so far liberated seems to be mainly hydrogen sulphide.

WELSH FIELD.[a]

LOCATION AND OUTLINE OF DEVELOPMENT.

The Welsh field is located in secs. 21 and 22, T. 9 S., R. 5 W., about 3 miles northwest of Welsh, a town on the Southern Pacific Railroad in Calcasieu Parish, about 10 miles west of Jennings. (See fig. 10.) In an area 1,500 feet square 21 wells have been drilled since the summer of 1902, 17 of which have produced oil at some time or other. No one of these wells has ever been a large producer for any great period. In 1903 the production of the field was 25,162 barrels, a daily average of about 69 barrels. In August, 1904, the daily average production was between 300 and 400 barrels, the production for that year being 35,892 barrels. The production since then has been as follows: 1905, 10,000 barrels; 1906, 23,996 barrels; 1907, 47,316 barrels; 1908, 43,976 barrels, an average for the six years of 85 barrels a day. The gravity of the oil varies from 18° to 22° Baumé. The greater proportion of the production of the field is taken by the Welsh refinery and the Southern Pacific Railroad, the oil being converted into valuable lubricating products. The average price obtained for the oil is between 75 cents and $1 a barrel.

TOPOGRAPHY.

The site of the Welsh field is a gentle elevation on the otherwise flat coastal plain. This elevation is distinctly visible from a distance, rising between 5 and 10 feet above the plain, but its boundaries are not easily defined within narrow limits. The developed oil field coincides approximately with the elevated area. Around the edges of the developed field a sufficient number of dry wells (see list and description below) have been drilled to prove that the productive area is not very extensive.

GEOLOGY.

The sections on page 107, taken within the productive field and beyond its limits, show clearly the character and vertical distribution of the sediments passed through by the drill.

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[a] By I. Perrine. See Bull. U. S. Geol. Survey No. 212, 1903, p. 136; idem, No. 282, 1906, pp. 102 105; Rept. Louisiana Geol. Survey for 1907, p. 35.

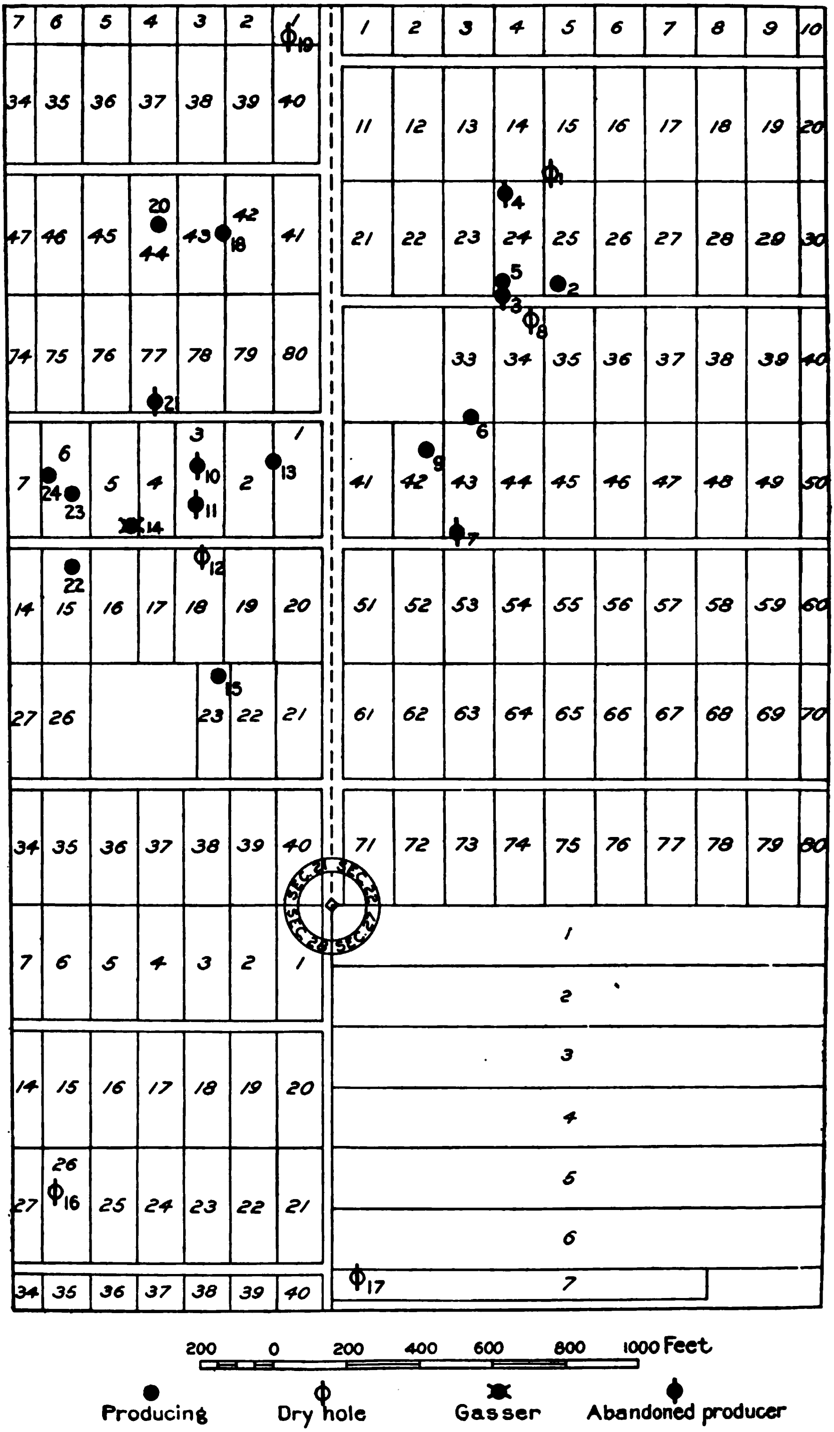

FIGURE 10.—Map of the Welsh oil field, Calcasieu Parish.

Logs of wells in and near Welsh field.

BUTLER No. 2 WELL.

[Received from J. H. Bowen, driller.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	65	65	Blue sand	40	702
Shale	83	148	Gray sand	40	742
Sand	150	298	Gravel	21	763
Gravel	107	405	Sand	58	821
Gumbo	20	425	Shale	21	842
Gravel	22	447	Sand	19	861
Sand	22	469	Gravel	63	924
Gravel	22	491	Gumbo	58	982
Gumbo	87	578	Shale	39	1,021
Shale	84	662	Oil sand	21	1,042

BUTLER No. 3 WELL.

[Received from J. H. Bowen, driller.]

Clay	48	48	Shale	46	610
Shale	47	95	Sand	103	713
Sand	211	306	Gravel	208	921
Gravel	189	495	Gumbo	105	1,026
Gumbo	69	564	Oil sand	25	1,051

WELSH LAND AND OIL DEVELOPMENT COMPANY'S WELL No. 5.[a]

[Received from J. H. Bowen, driller.]

Clay	44	44	Blue shale	68	659
Shale	107	151	Shale	22	681
Sand	43	194	Sand	40	721
Gravel	98	292	Gravel	109	830
Sand	24	316	Gumbo	21	851
Gravel	148	464	Gravel	43	894
Gumbo	64	528	Gumbo	75	969
Gravel	63	591	Oil sand	17	986

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[a] Completed July 14, 1906. The well blew out at 986 feet and has since been deepened to 2,000 feet, finding 200 feet of oil sand with shells. Oil was found at 986, 1,200, 1,400, 1,700, and 1,800-2,000 feet. From 1,000 to 2,000 feet the drill passed through gumbo, shale, shells, and sand.

BIG MOUND OIL AND GAS COMPANY'S WELL, 7 MILES SOUTHEAST OF WELSH.

[Received from W. N. West, driller.]

Red clay	95	95	Blue clay	25	785
Very fine sand with water	51	146	Sand	320	1,105
Blue clay	84	230	Gumbo	15	1,120
Sand and gravel with much water	230	460	Sand	45	1,165
Blue clay	12	472	Blue clay	105	1,270
Sand	38	510	Sand	38	1,308
Blue clay	55	565	Blue clay	102	1,410
Sand	35	600	Sand	65	1,475
Blue clay	95	695	Shale	55	1,530
Sand	65	760	Sand (well abandoned)	21	1,551

INDEX AND DESCRIPTION OF WELLS.

WELLS IN THE WELSH OIL FIELD.

The numbers at the left in the subjoined list correspond to those used on the map, figure 10.

1. Proven field; never produced; hole only remains.
2. Hilltop No. 1; producing very little oil; passed through 7 feet of good sand, as did other Hilltop wells.
3. Hilltop No. 2; hole full of junk; produced at the rate of 12 barrels an hour for seven days.
4. Hilltop No. 3; hole only remains; formerly produced from 5 to 10 barrels per day.
5. Hilltop No. 4; producing scarcely any oil.
6. Southern Pacific No. 1; 1,006 feet deep; fishing for tools lost; will pump later if successful in recovering tools.
7. Southern Pacific No. 2; abandoned producer; hole only remains.
8. Southern Pacific No. 3; a dry hole.
9. Metropolitan; 996 feet deep; pumping 20 to 25 barrels a day.
10. Welsh Oil and Land Development Company No. 1; abandoned producer; only hole remains.
11. Welsh Oil and Land Development Company No. 2; abandoned producer; hole alone remains.
12. Welsh Oil and Land Development Company No. 3; a dry hole; ruined by blowout at 1,100 feet.
13. Welsh Oil and Land Development Company No. 4; 1,020 feet deep; will be repaired; was a 40-barrel producer when pumped.
14. Southwestern Oil Company No. 1; gassed three or four hours when brought in, but has never produced either oil or gas since.
15. Boss & McFadden; 1,030 feet deep; best well in the field at present (November 15, 1908); fishing for screen.
16. Texas Company No. 1; a dry hole at 1,200 feet.
17. Decatur Oil and Mineral Company; a dry hole at 2,012 feet; passed through 40 feet of good sand at 1,140 feet, and had a show of oil at 1,400 feet and at 1,600 feet.
18. Colorado-Texas; a dry hole at 2,340 feet; on being shut off to a depth of 1,000 feet a producing well was brought in; a strainer was being put in the hole November 15, 1908, and the well may be called a producer.
19. Brown-Lively; a dry hole at 1,100 feet; produced some water, but no oil.
20. Taber No. 1; 1,025 feet deep; will be a producer; repairs being made November 15, 1908.
21. Welsh Oil and Land Development Company No. 5; 2,000 feet deep; hole only remains; passed through good sand between 1,800 and 2,000 feet.
22. Butler No. 1; pumping.
23. Butler No. 2; pumping.
24. Butler No. 3; pumping. All three Butler wells combined produce about 40 barrels a day on the average.

WELLS DRILLED AROUND THE FIELD PROPER.

The Decatur Company drilled two wells 6 miles north of the field to depths of about 1,200 feet and found no oil.

Near the Decatur wells the Spindletop well, 1,700 feet deep, found only a showing of gas at about 1,000 feet.

The Boss-McFadden well 1,500 feet northeast of the field was drilled to a depth of 2,000 feet, and, though a dry hole, is reported to have found a showing of oil at 1,400 and 1,600 feet.

A well put down one-fourth mile due east of Southern Pacific No. 1 to a depth of 2,000 feet struck no oil sand. Farther east at Roanoke, 5 miles east of Welsh, are two dry holes between 1,100 and 1,200 feet deep.

The Texas Company drilled a well 2,000 feet deep 1½ miles southeast of the field and got a dry hole.

About 6 or 7 miles southeast of Welsh the Big Mound Oil and Gas Company drilled a dry hole 1,551 feet deep.

A water well 2 miles south of the center of the field struck gas with about the same pressure as in the field at 250 feet.

The Texas Company got a dry hole at 1,100 feet about 800 feet west of the McFadden well.

The Wildcat well, 1½ miles west of the field, found no traces of oil.

GAS.

All of the oil in the Welsh field is found at depths differing little from 1,000 feet, in uncompacted sands overlain by a single thick bed of gumbo or by a succession of beds in which gumbo is prominent. Gas is found in considerable quantities, its presence in a water well about 250 feet deep on the Wood farm being the principal indication which led to drilling, though the existence of the mound itself must have been regarded as significant. The gas is found at the same horizon as the oil.

SALT WATER.

The amount of salt water pumped with the oil at Welsh is considerably greater than that of the oil itself. Trouble has been experienced in the separation of the oil from the water accompanying it, the process requiring an inconveniently long time and a high temperature. After the separation the oil may be used for fuel, though in its constitution it differs sufficiently from the other Coastal Plain oils to cause a slight inconvenience in using it in the same burners. The oil obtained in the Welsh field is said to be the best for lubricating purposes in the whole southern region.

CEDAR SALINE.

Location.—The Cedar saline lies 3 miles southeast of Winnfield, Winn Parish, in secs. 30 and 31, T. 11 N., R. 2 W. For details of the surroundings, see Plate I of the Louisiana Geological Survey's report for 1907 (Bulletin 5). A view of this saline is given in Plate IX of the present volume.

History and geology.—Extended barren salt licks, salt-water springs, and an abundance of gas bubbling up through the saline waters have tended to draw attention to this remarkable locality and to encourage the hope that it may some day prove to be an oil and gas field. As early as the summer of 1904 one well at least had attained a depth of 750 feet and had experienced a decided blow-out. Another well was only 100 feet deep, a 10½-inch bit being held fast in the hole. In 1907 the amount of gas escaping from the deeper well was noteworthy; it was accompanied by a strong flow of salt water. There seems to be no doubt that a very fair gas well could be obtained here. However, all energy so far has been directed to finding oil. During the spring of 1907 J. D. Pace, of Winnfield, and Brown Brothers, drillers, were engaged on a well in which they struck, at 78 feet, rock of the toughest type for drilling, which continued practically to 1,000 feet. Work was discontinued at a depth of a little more than 1,200 feet, where the drill encountered "volcanic rock." Specimens sent to the writer by Mr. Pace, however, showed clearly that the supposed igneous rocks consisted of gypsum and limestone, darkened by hydrocarbons and pyrites. It is understood that the well will be deepened. The location of the well seems not unfavorable to furnish a fair test of the oil capabilities of the vicinity, and it is reasonable to expect that gas and probably oil will eventually be found locally in commercial quantities somewhere in this neighborhood.

Details regarding the geology of this region are given in the Louisiana Geological Survey's report for 1907 (Bulletin 6), page 10.

STRATUM OIL AND GAS FIELDS AND PROSPECTS.

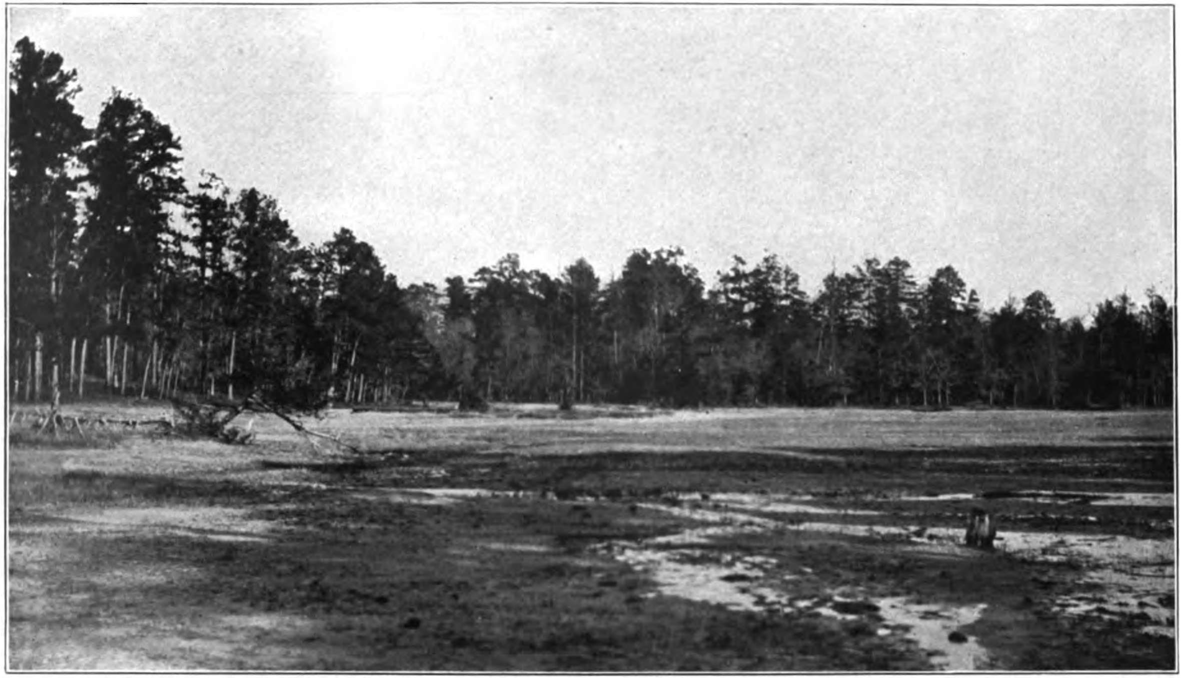
It has already been stated that oil and gas occur in Louisiana in normally stratified rocks belonging to well-known geologic horizons. These horizons, so far as known, are Upper Cretaceous, lower Eocene, and Quaternary. A synoptical summary of such occurrences appears on pages 29–34. Details for the benefit of those actually working in these various fields are given below.

CRETACEOUS HORIZONS.

CADDO OIL AND GAS FIELD.

GENERAL LIMITS AND LOCATION.

For general purposes the Caddo field may perhaps be defined as a more or less quadrangular area in Caddo Parish, La., extending from Mooringsport on the south to Vivian on the north, and from the Louisiana-Texas state line on the west to Dixie on the east. It is located in the north corner of the Sabine uplift. (See fig. 1.) The areas of greatest present development are shown on the index map (fig. 11) and on figures 12 to 15. However, even as far south as Shreveport gas has been found in considerable quantities at depths of less than 1,000 feet, and there are reasons for hoping that in



CEDAR SALINE, 3 MILES SOUTHEAST OF WINNFIELD.

various places throughout this great structural unit gas and oil may have been collected in paying quantities. Between such fields of future development there are doubtless extensive barren areas, and the localities that are productive will doubtless receive special names. In the Caddo field as above defined there are large areas that are barren of oil or gas. This brings about the local usage of such names as the Vivian, Lewis, Pine Island, Oil City, and Mooringsport fields; but the limits of such subdivisions are ill defined.

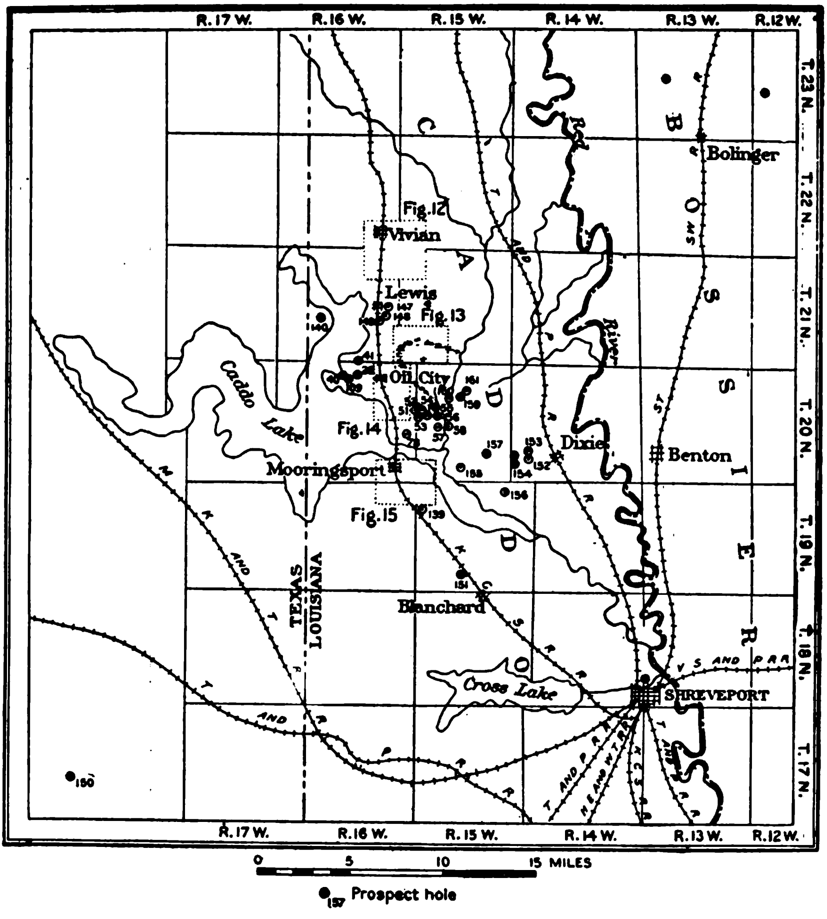


FIGURE 11.—Index map showing areas mapped in figures 12 to 15, also widely scattered prospect wells near the Caddo oil field, Caddo Parish. (See list of numbers, pp. 112-117.)

The numbers of the wells shown on figures 11, 13, 14, and 15 correspond to those in the list following.

Index to wells shown on figures 11 and 13–15.

1. Offenhauser No. 1, small derrick, Caddo Gas and Oil Co.
2. Offenhauser No. 2, Caddo Gas and Oil Co.
3. Smith No. 2, Caddo Gas and Oil Co.
4. Smith No. 3, Caddo Gas and Oil Co.
5. Big Four No. 2.
6. Big Four No. 1.
7. Producers No. 1.

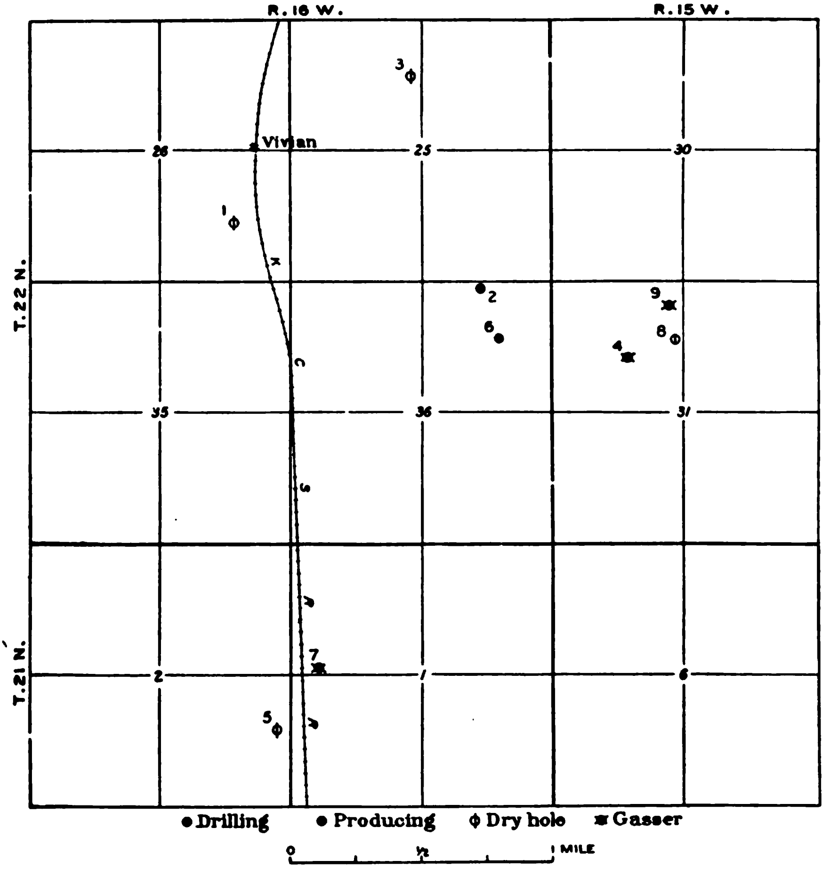


Figure 12.—Map of Vivian district, Caddo oil field. (See index maps, figs. 11 and 16.) 1, Caddo Gas and Oil Co., Hiner No. 1; 2, Vivian Oil Co., Edwards No. 1; 3, B. G. Dawes and Gulf Refining Co., Posey No. 1; 4, B. G. Dawes and Gulf Refining Co., Heilperin No. 1; 5, Producers, Harrell No. 1; 6, Vivian Oil Co., Childs No. 1; 7, Caddo Gas and Oil Co., Pardue No. 1; 8, McCann & Harper, Pitts No. 1; 9, McCann & Harper, Pitts No. 2.

8. Brown Brothers No. 1.
9. Smith No. 1, Caddo Gas and Oil Co.
10. Producers No. 6, Caddo Oil and Mining Co.
11. Producers No. 5, Caddo Oil and Mining Co.
12. Producers No. 1, Murray et al.
13. Producers No. 1, Black Bayou.
14. Richardson No. 1, Pitts, Reliance No. 1.

15. Richardson No. 2, Pitts, Reliance No. 2.
16. Shreveport Petroleum Co. No. 1, Townsite.
17. Savage Brothers & Morrical, No. 1.
18. Texla No. 2.
19. Texla No. 3.
20. Daniels & Alday No. 1, Watkins.
21. Producers No. 2, Heilperin & Liebman.
22. Producers No. 1, Heilperin & Liebman.
23. Smith No. 4, Caddo Gas and Oil Co.
24. Offenhauser No. 3, Caddo Gas and Oil Co.
25. Producers No. 1, Evans.
26. Producers No. 1, Ruddersdorf.
27. Producers No. 1, Homestead.

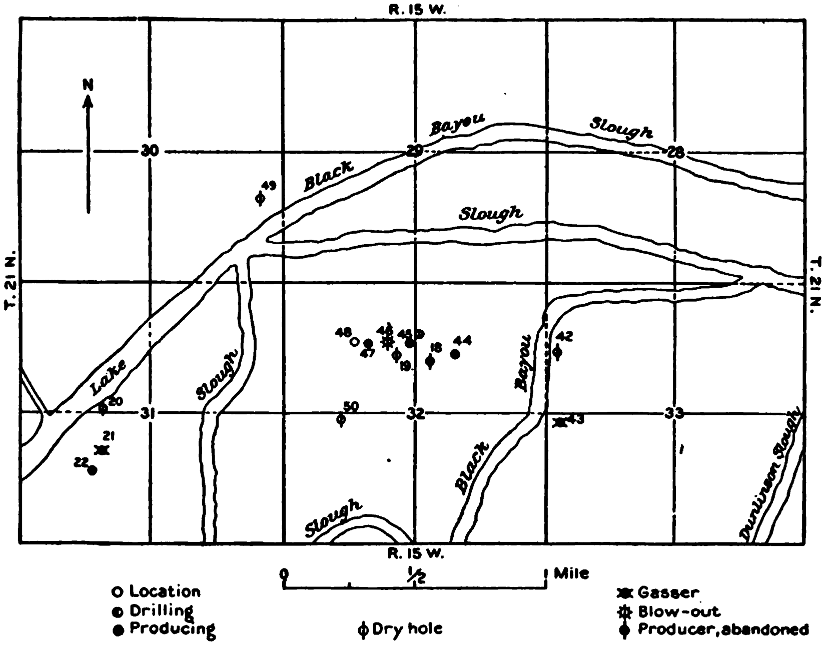


FIGURE 13.—Map of Pine Island district, Caddo oil field. (See index maps, figs. 11 and 16, and list of numbers, pp. 112-117.)

28. Blanchard No. 1, Surrey.
29. Blanchard No. 2, Surrey.
30. Jolly No. 1; Culliman & Jolly No. 1.
31. Producers No. 8, Caddo Oil and Mining Co., derrick only.
32. Producers No. 2, Murray et al.
33. Producers No. 7, Caddo Oil and Mining Co.
34. Lillie No. 1.
35. Enterprise No. 2.
36. Enterprise No. 1.
37. Smith No. 5, Caddo Gas and Oil Co.
38. C. G. Dawes Trustee No. 1.
39. C. G. Dawes Trustee No. 2.

40. Atlanta and Shreveport No. 1; old No 2; Latex No. 1.
41. Blanchard No. 1; Graham.
42. Dixon Oil and Pipe Line Co. No. 1.
43. Dixon Oil and Pipe Line Co. No. 2.

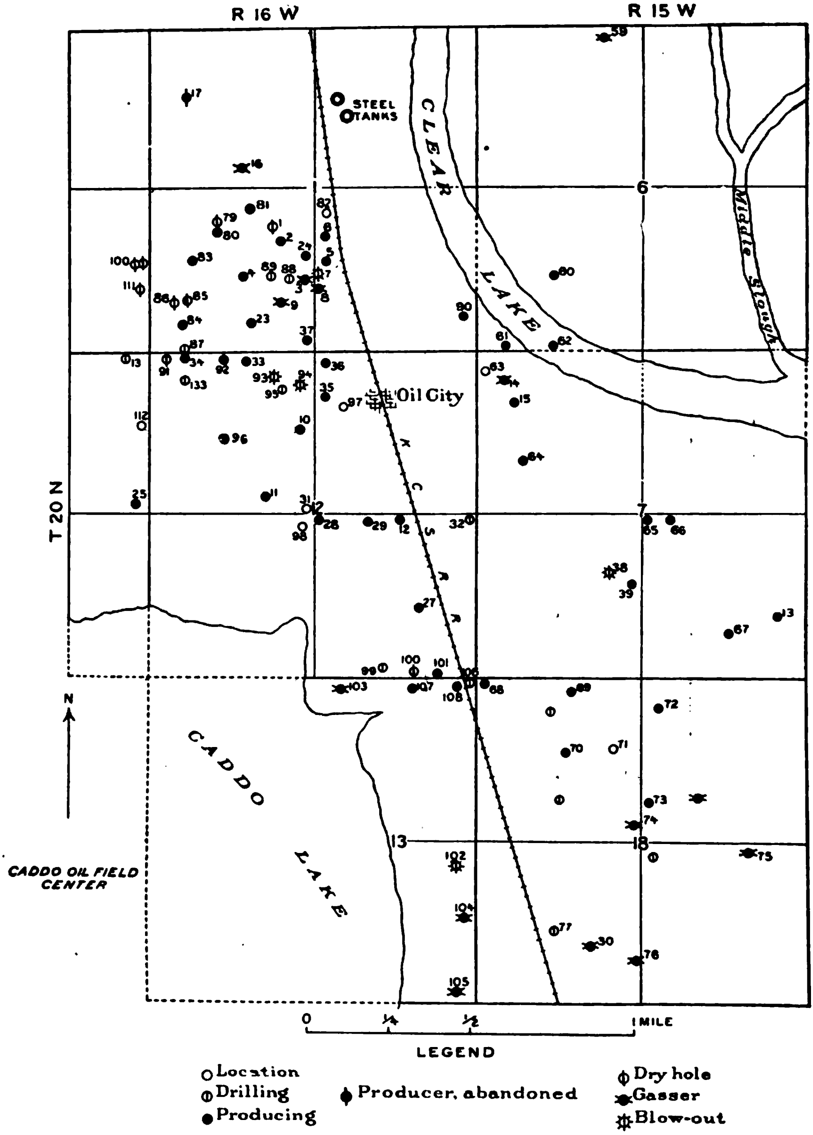


FIGURE 14.—Map of central part of Caddo oil field. (See index maps, figs. 11 and 16, and list of numbers, pp. 112-117.)

44. Texla No. 1.
45. Richardson No. 5.
46. Richardson No. 3.
47. Richardson No. 4.

48. Richardson No. 6.
49. Producers No. 1, Harrel 3,000 feet.
50. Trees No. 1, Heilperin & Liebman.
51. Jolly No. 2, Louisiana Gas Co.
52. Crawford No. 1, McGuire.
53. Huckaby No. 1, McGuire.
54. Byron No. 1, McGuire.
55. School No. 2, McGuire.
56. School No. 1, McGuire.
57. Barnhart No. 1, McGuire.
58. Barnhart No. 2, McGuire.
59. Producers No. 1, Leonard.

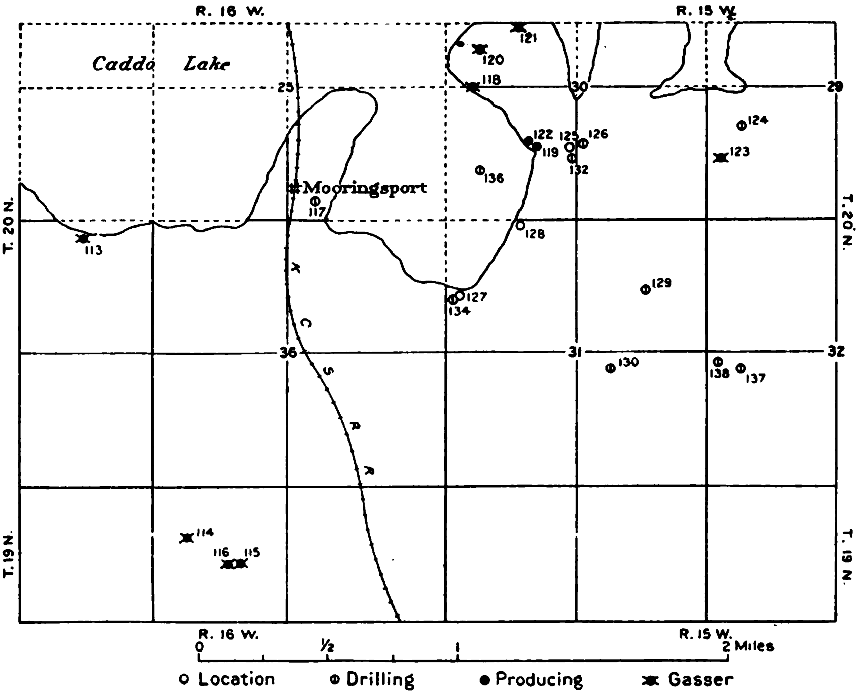


FIGURE 15.—Map of Mooringsport district, Caddo oil field. (See index maps, figs. 11 and 16, and list of numbers, pp. 112-117.)

60. Merchant No. 1.
61. Broussard No. 1, Fee.
62. Broussard No. 2, Fee.
63. Guffey No. 1, Pitts.
64. Reliance No. 3, Pitts.
65. Filer No. 2, sec. 7.
66. Filer No. 1, sec. 7.
67. Producers No. 2, Black Bayou.
68. Producers No. 1, Murray, Colquitt & Hardy.
69. Producers No. 2, Lane.
70. Producers No. 4, Lane.
71. Producers No. 3, Lane.

72. Filer No. 1, sec. 18.
73. Producers No. 3, Black Bayou.
74. Evans No. 2, McGuire.
75. Evans No. 3, McGuire.
76. Evans No. 1, McGuire.
77. Broussard No. 1, Brown.
78. Gulf Refining Co. No. 1, Curtis.
79. Brown No. 1.
80. Offenhauser No. 1, Caddo Gas and Oil Co.
81. Offenhauser No. 4, Caddo Gas and Oil Co.
82. Heywood No. 1, Fee.
83. Hunter No. 2, Smith No. 1.
84. Caddo Lake Oil and Pipe Line Co. No. 1, Caddo Gas and Oil Co.
85. Caddo Lake Oil and Pipe Line Co. No. 2, Caddo Gas and Oil Co.
86. Richardson No. 1, D. C. Richardson.
87. Caddo Lake Oil and Pipe Line Co. No. 3, Caddo Gas and Oil Co.
88. Smith No. 6, Caddo Gas and Oil Co., Location.
89. Location of derrick torn down.
90. Mansfield No. 1.
91. Lillie No. 2.
92. Producers No. 1, T. M. Richardson.
93. Producers No. 2, Blowout, Caddo Oil and Mining Co.
94. Producers No. 3, Blowout, Caddo Oil and Mining Co.
95. Producers No. 4, Caddo Oil and Mining Co.
96. Producers No. 1, Lane.
97. Enterprise No. 3.
98. Blanchard No. 4, Surrey.
99. Blanchard No. 3, Surrey.
100. Producers No. 2, Homestead.
101. Producers No. 3, Homestead.
102. Gilbert No. 1, gas, Caddo Gas and Oil Co.
103. Gilbert No. 2, gas, Caddo Gas and Oil Co.
104. Gilbert No. 3, gas, Caddo Gas and Oil Co.
105. Gilbert No. 4, gas, Caddo Gas and Oil Co.
106. Gilbert No. 5, gas, Caddo Gas and Oil Co.
107. Gilbert No. 1, oil, Caddo Gas and Oil Co.
108. Gilbert No. 2, oil, Caddo Gas and Oil Co.
109. Old No. 3, Atlanta and Shreveport No. 2, Latex No. 2.
110. Heywood & Savage No. 1.
111. Producers No. 1, J. W. Holt.
112. Lillie No. 3, Hill tract.
113. Croom Clubhouse No. 1, Caddo Gas and Oil Co.
114. Noel No. 2, Caddo Gas and Oil Co.
115. Noel No. 1, Caddo Gas and Oil Co.
116. Noel No. 3, Caddo Gas and Oil Co.
117. McCormick No. 1, Croom.
118. Hostetter No. 1, Caddo Gas and Oil Co.
119. Hostetter No. 2, Caddo Gas and Oil Co. (Guffey No. 1).
120. Hostetter No. 3, Caddo Gas and Oil Co.
121. Hostetter No. 4, Caddo Gas and Oil Co.
122. Guffey No. 2, Hostetter.
123. Harris No. 1, Caddo Gas and Oil Co.
124. Gulf Refining Co.
125. Gulf Refining Co.
126. Producers No. 1, Producers.

127. Thompson No. 1, McCormick.
128. Guffey No. 1, Christian.
129. Caddo Gas and Oil Co.
130. Caddo Gas and Oil Co.
131. Busch-Eyerett No. 1, Etchison.
132. Gulf Refining Co., Hostetter No. 3.
133. Lillie No. 3.
134. Staiti No. 1, Ward tract.
135. Gulf-Broussard.
136. Gulf Refining Co., So. Relle, No. 1.
137. Cook No. 1, Caddo Gas and Oil Co.
138. Gulf Refining Co., Cook No. 1.
139. Producers No. 1, Milam.
140. Heywood No. 2, Savage.
141. Curtis No. 1, May Oil Co.
142. Producers No. 1, White.
143. Richardson No. 7, Pine Island.
144. Gulf Refining Co., Plantation No. 1.
145. Filer No. 2, sec. 18. Gas well.
146. Rogers No. 1, Lewis, La.
147. Rogers No. 2, Lewis, La.
148. Rogers No. 3, Lewis, La.
149. Trees Oil Co., Styles No. 1.
150. Blocker well, Tex.
151. Marshall Gas Co. No. 1, Cole, Blanchard, La.
152. Dixie Oil and Pipe Line Co. No. 3.
153. F. Hauser, North No. 1.
154. Dixie Oil and Pipe Line Co. No. 2.
155. Benedum & Tree Co., Ballard Oil Co. No. 1.
156. Dixie Oil Co., Glassell & Adger No. 1.
157. G. F. Hausener, J. C. Dixon No. 1.
158. Brick-yard well, Shreveport.
159. Black Bayou Oil Co. No. 1, Glassell.
160. Black Bayou Oil Co. No. 2, Alexander.
161. Black Bayou Oil Co. No. 3.
162. Cooper & Heard, Winnfield, La.
163. Ruston oil well.

From a point 2 miles south of Vivian northward, from James Bayou westward, and from Mooringsport southward the rolling and locally dissected uplands of the Tertiary formations may be found. Rarely, however, does an area of any considerable size pass above the 300-foot contour. Plate XI, *B*, is reproduced from a photograph of a portion of the steep bank at Potters Point, on the north shore of Caddo Lake, just over the Texas line. This particular bank, above the point where the man is shown in the picture, has been rendered unusually abrupt by a landslide that has carried down hundreds of tons of earth and formed a short terrace with a basin-like depression behind. The large trees and the man are in this depression. Near the base of the bluff the sharply incised wave-formed cliffs of the "raft period," so well described by Veatch,[a] are clearly shown. It is very evident that, as Veatch maintains, the steep banks to be seen some distance above the usual level of the lakes in this part of Louisiana were carved out by wave erosion during the period when the main Red River channel was clogged by a log jam or "raft." Yet it is interesting to note that but two years ago the surface of Caddo Lake stood for weeks almost at "raft period" level, as the débris in the foreground of Plate XI, *B*, clearly shows. It is stated that seventeen years ago the waters of this lake stood several feet higher still. Plate X, *A*, shows a part of the lake.

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[a] Prof. Paper U. S. Geol. Survey No. 46, 1906, pp. 60-63.

At present the general level of Caddo Lake must be gradually lowering, for the "rapids" at the southeast terminus of Soda Lake are gradually lowering the outlet for all this system of lakes and bayous. (See Pl. XI, *A;* also fig. 11.) It is quite evident, therefore, that in the future Caddo Lake and the connected bodies of water will show a far greater range in stages of water than formerly. They will stand for a short time occasionally at "raft period" level, but will drop quickly to medium or low stages.

CLIMATE.

Although the subject of climate is not mentioned in most geologic reports, it is evident that in attempting to show the conditions that must be met in the production of oil or gas in a particular field, certain climatic peculiarities may be worthy of serious consideration. The figures obtained by Observer Wright at the United States Weather Bureau station at Shreveport indicate fairly well the conditions in the Caddo field, though Caddo is somewhat hotter and more humid. The Shreveport figures are as follows:

Temperature, monthly average for twenty years:

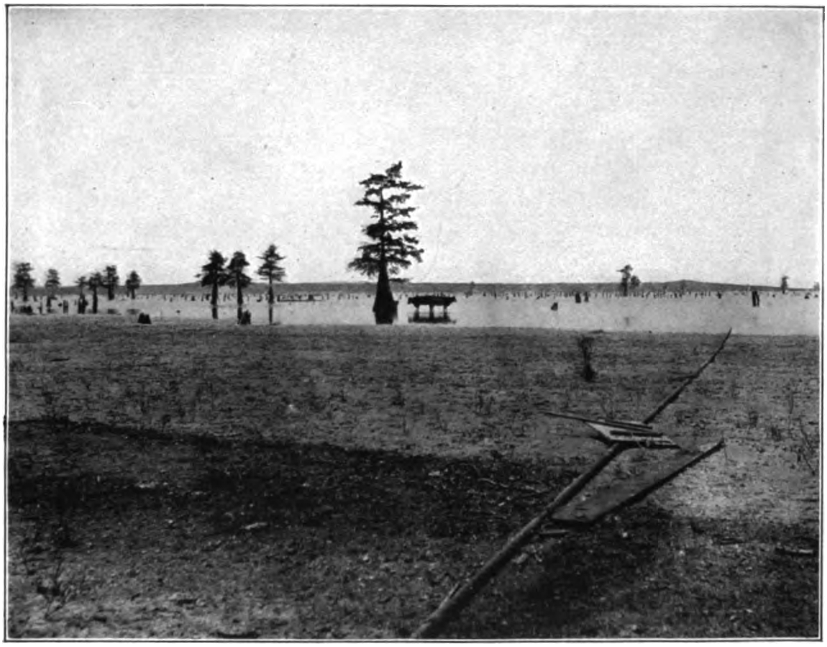
	°F.		°F.		°F.
January	45.8	May	73.3	September	74.8
February	51.5	June	79.9	October	65.4
March	58.1	July	82.7	November	54.2
April	66.1	August	81.5	December	49.5

General average for twenty years, 65.2° F. Hottest days in the year generally in July, showing maxima of 96° to 107° F.

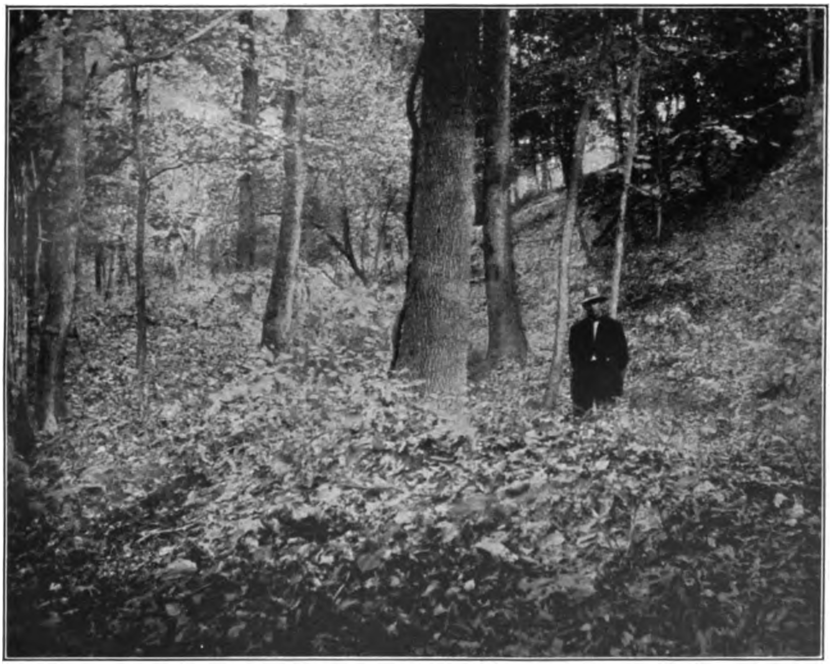
Precipitation, monthly average for twenty years, 4.3 inches. August has but little over 2 inches; April has 5.5 inches.

Relative humidity, 72.5—that is, the air contains on an average 72.5 per cent of the moisture it is capable of holding at the various temperatures when observations were made.

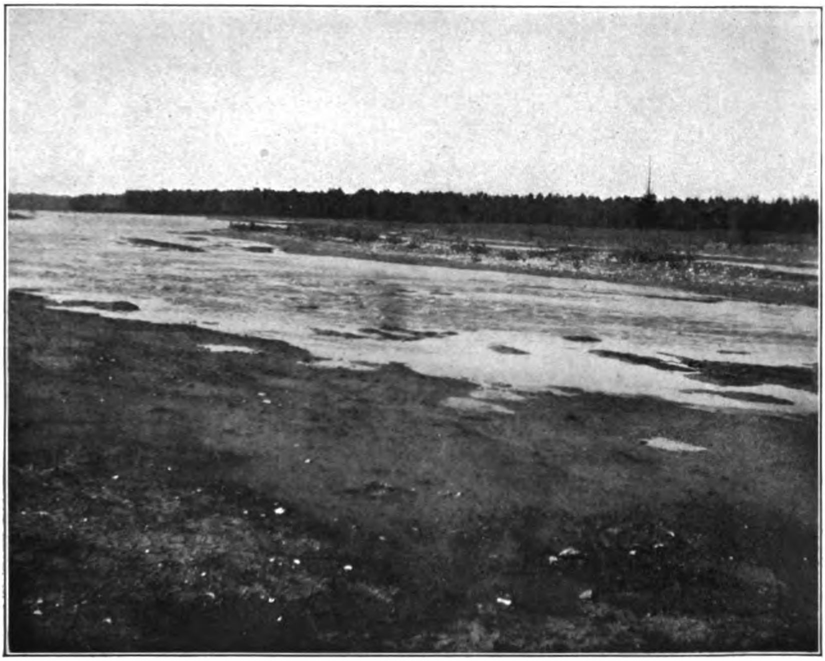
In general it may be said that the months October to January are delightful, February to May tolerable, but June to September trying to even strong constitutions. Malaria is very prevalent, owing doubtless to the swarms of mosquitoes that infest the region. Ticks and "red bugs" add greatly to the discomfort of the workmen. Drinking water is scarce and generally of a very inferior quality.



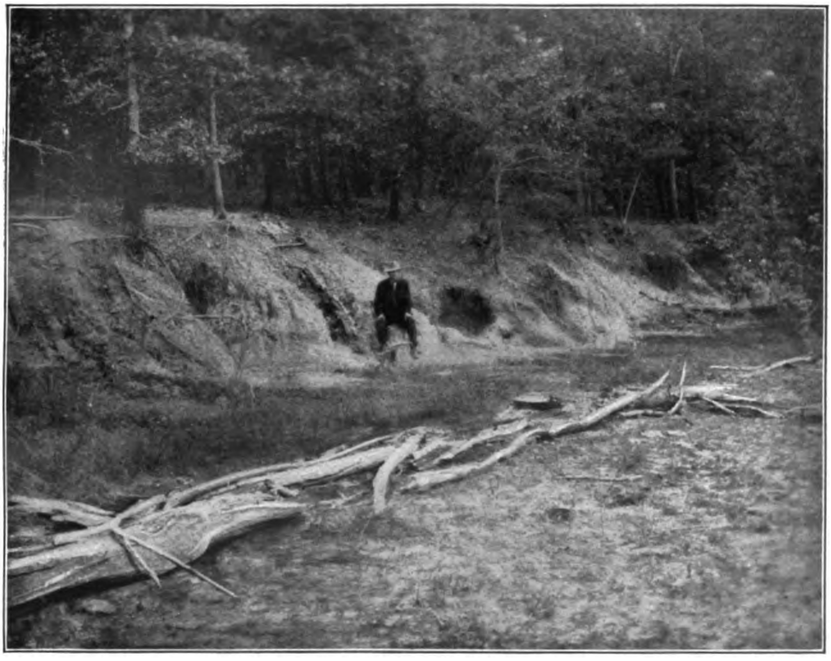
A. CADDO LAKE, LOOKING SOUTH FROM A POINT ABOUT 1 MILE SOUTHWEST OF OIL CITY.



B. LANDSLIDE TERRACE ON NORTH BANK OF CADDO LAKE, JUST WEST OF TEXAS-LOUISIANA STATE LINE.



A. THE RAPIDS, AT MOUTH OF SODA LAKE, 10 MILES SOUTHEAST OF MOORINGSPORT.



B. POTTERS POINT, NORTH SHORE OF CADDO LAKE.

Showing wave-formed bluff of raft-period stage of water level and débris left by recent high waters

GEOLOGY OF THE CADDO FIELD.

GENERAL OUTLINE.

The areal geology of northwestern Louisiana, eastern Texas, and southwestern Arkansas has been excellently set forth in Professional Paper 46 of the United States Geological Survey, by A. C. Veatch. The map herewith given as Plate XII is a copy of a map appearing in that paper, modified in only a few details. The section at the left of the plate is also a modified form of Veatch's section.

In the mapping the Quaternary, Tertiary, and Cretaceous systems, already described in outline, are subdivided into series and formations. In the territory extending from Mooringsport to Vivian, besides the more or less omnipresent Quaternary veneering, the Eocene Wilcox ("Sabine") formation and Claiborne group constitute the surface rocks. Section A–A′, at the left of Plate XII, shows that many other formations underlie the Caddo field within less than 2,000 feet of the surface. These formations must be briefly described before an intelligent description of the geology of the Caddo field can be given. As the younger beds above are penetrated before the older lower beds in the process of drilling, the description will observe this natural sequence. The generalized section given on page 30 shows what formations are penetrated in drilling in the Caddo field and about at what depths.

QUATERNARY SYSTEM.

An excellent discussion of the history of this and adjacent regions during Quaternary time is given by Veatch in the paper already cited. On Plate XII of the present volume the more conspicuous Quaternary deposits are indicated. Between Mooringsport and Oil City there are no less than 30 feet of red and gray sands and clays that are referable to these comparatively recent deposits. (See Pl. XIII, *B*.) Their reddish hues are more pronounced toward the base and owe their origin clearly to the characteristic color of the deposits of Red River. Calcareous nodules are abundant in certain layers; no fossils have thus far been seen. So far as the oil industry is concerned, the Quaternary deposits are of little moment, save perhaps in some places where the tenacious red-clay layers furnish good impervious material in which to excavate earthen storage tanks.

TERTIARY SYSTEM.

Of the four series of the Tertiary system, only the oldest, the Eocene, is represented in the Caddo field. Moreover, only the two lower formations of this series occur extensively within the boundaries of the proved field. In the generalized section given above only the Wilcox ("Sabine") and Midway formations are mentioned, but Plate XII and the accompanying section show that certain areas of Claiborne deposits occur in the vicinity of Vivian.

There are no sharp lines of division between the different Eocene formations in the Caddo field. The Claiborne group is, however, not only usually more fossiliferous then the underlying Wilcox, but also more ferruginous. The Wilcox is especially characterized by considerable beds of lignite and large, bowlder-like calcareous concretions. The Midway in the Caddo well is but slightly different from the darker lignitic layers of the Wilcox above or the tough dark Arkadelphia clay below. In some of the wells a limestone is struck that appears to be of the Midway horizon.

Claiborne group.—Plate XII shows how the Claiborne group borders the Sabine uplift. It is represented only by patches in Gregg, Marion, and Cass counties, Tex., and Caddo and Bossier parishes, La., where it has been for the most part carried away by long-continued erosion. It spreads out extensively in Rusk and Nacogdoches counties, Tex., and Bienville and Winn parishes, La., where the dip is slight, but it narrows down in Sabine Parish, where a steep dip carries it beneath the later Tertiary deposits.

In the Caddo field, as already defined, marine Claiborne fossils have been found in but one locality, by the roadside about one-fourth mile east or east-southeast of the railway station at Vivian. Here, as at Roberta, Bolinger, and Plaindealing, in Bossier Parish, and in Ouachita County, Ark., the fossils are in the form of casts in very ferruginous indurated layers. From their appearance, which is very different from that of the fossil species so abundant and characteristic of the Claiborne from Bienville Parish to Nacogdoches County on the south, it is inferred that either these northern forms existed under considerably different conditions from their southern relatives or they represent a somewhat older type of life.[a] It is possible that the

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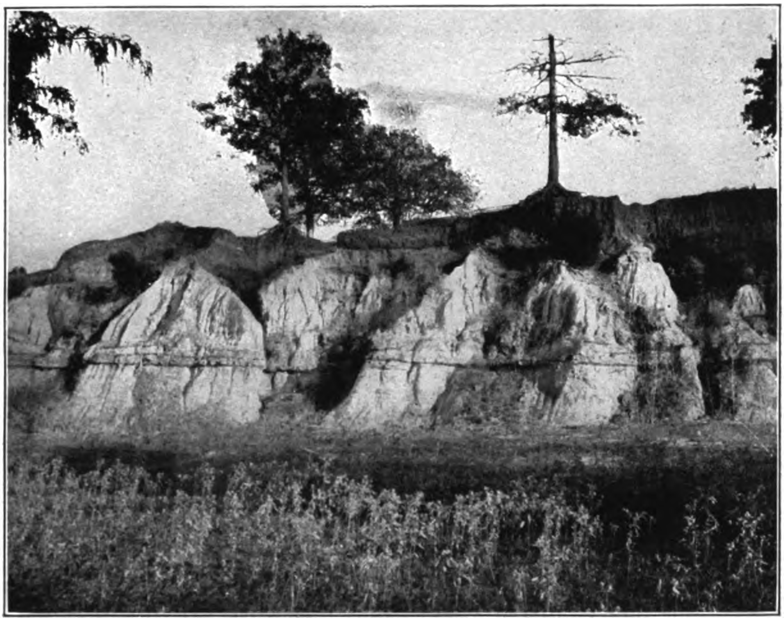
[a] Seventeen years ago the writer collected at Walnut Bluff, Ouachita County, Ark., and near Plaindealing, La., a few fragments of fossils that were referred to a lower Claiborne horizon. Recently he has collected somewhat more extensively in the locality from Plaindealing northward. At Pope Joy cut, between Plaindealing and Bolinger, in a friable red sandstone on the east side of the railway, were found casts of small *Venericardia planicosta*, *Cytherea* cf. *bastropensis*, and what seems to be the smooth valve of *Ostrea sellæformis*.

Just north of the old Roberta station, in a cut between Bolinger and Arkana, in an oolitic ferruginous slightly indurated sandstone on the east side of the track the writer collected a number of casts and practically exhausted the available material. These casts show *Venericardia planicosta*, *Cytherea bastropensis*, *Tellina mooreana*, *Barbatia*, *Yoldia* (*Adrana*) cf. *aldrichiana*, *Modiola texana*, *Levifusus trabeatus*, *Volutilithes petrosus*, *Turritella carinata*, *Fusus bastropensis*, *Cancellaria tortaplica*, *Cornulina armigera* (very small), *Natica*, *Corbula*, *Tornatellæa*, fish scale, coral (*Balanophyllia angustidens*). A few miles to the northeast of this locality in ferruginous beds of this horizon *Pteropsis conradi* and a species of *Flabellum* have been found. The fauna collected at Walnut Bluff contains *Venericardia planicosta*, several forms of *Cytherea*, *Tellina*, probably *T. mooreana*, *Levifusus trabeatus*, *Cardium harrisi*, and a *Terebra*, probably *T. houstonia*, though very small and imperfect.

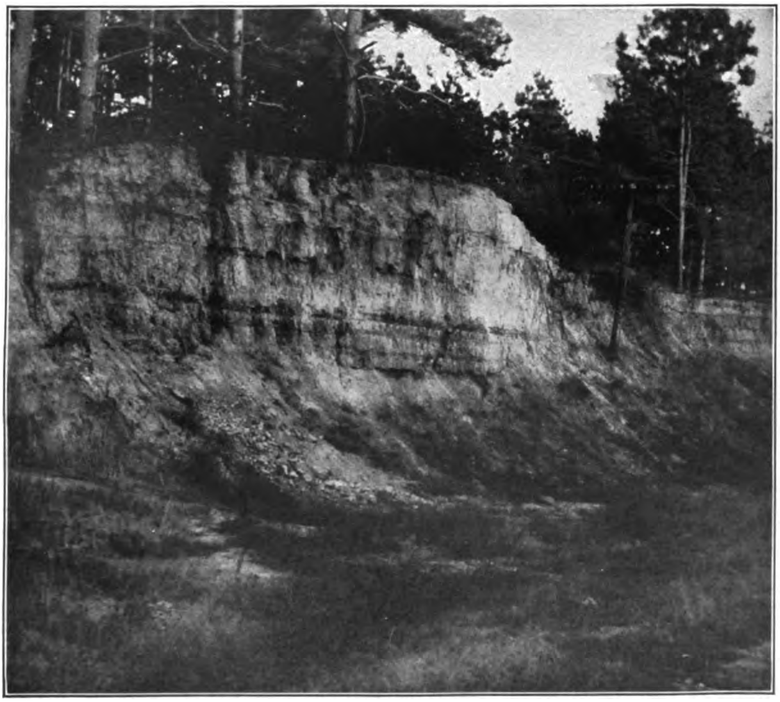
This fauna of the Red Lands of northern Bossier Parish, appearing again at Walnut Bluff, Ark., comprises a very different assemblage of species from the ordinary lower Claiborne *Ostrea falciformis*—*Orbitolina* fauna. In fact, Wilcox affinities are suggested. The small *Cornulina armigera* is of the archaic form, with one row of spines; *Cardium harrisi* belongs with the *C. toumeyi* and *C. hatchetigbeense* section of *Cardium*. *Fusus bastropensis* is related to *F. ottonis*. However, *Terebra houstonia*, *Flabellum* (upper Eocene type) and the abundance of good-sized *Cytherea* indicate that these Red Lands may with propriety be left in the lower Claiborne, where they were placed seventeen years ago.

The Claiborne group of southern Arkansas and northern Louisiana has hitherto been divided into the Cockfield formation and the so-called "Lower Claiborne." For the latter the name St. Maurice formation, from one of the places where the "Lower Claiborne" is typically exposed, has recently (Science, new ser., vol. 31, April 1, 1910, p. 502) been introduced.

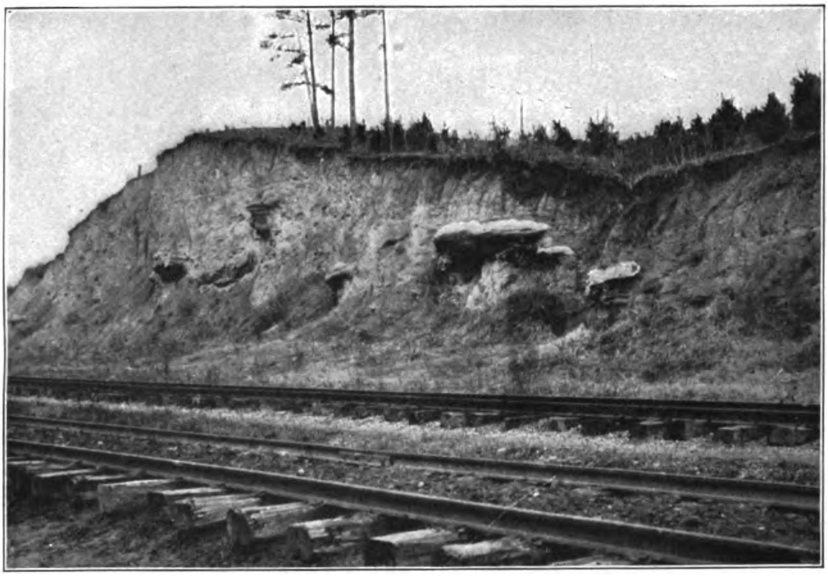


A. SOUTH BANK OF CADDO LAKE AT MOORINGSPORT.

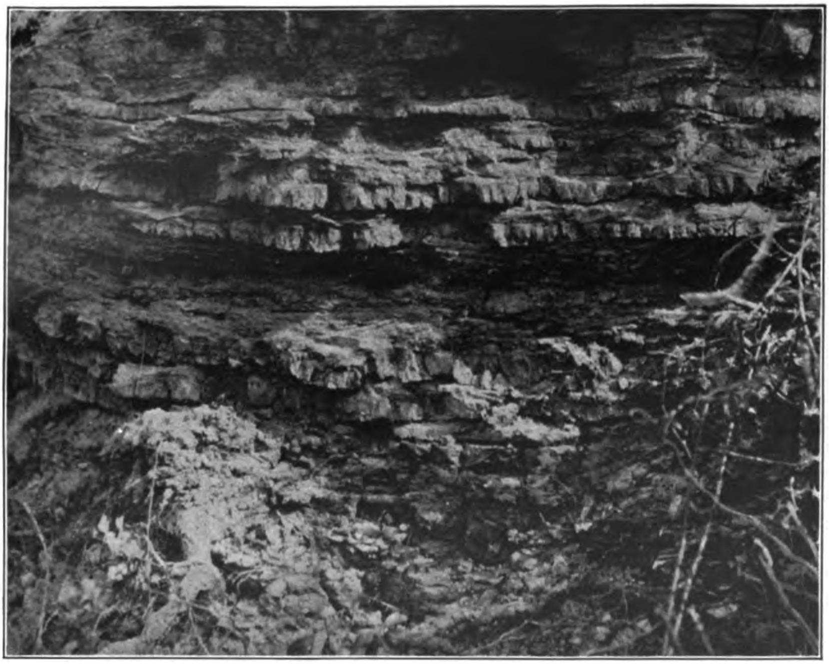
Showing Eocene Wilcox beds to 1 foot above ferruginous ledge at left and to 2 or 3 feet above same ledge at right; deposits above are all white and red clays, sands, and gravel of Quaternary age. This is a wave-formed bluff dating from the "raft period."



B. RED AND GRAY CLAY AND LOAM BEDS (QUATERNARY), EAST BANK OF RAILROAD CUT, 1½ MILES NORTH OF MOORINGSPORT.



A. CALCAREOUS CONCRETIONS IN SANDS OF WILCOX ("SABINE") FORMATION, SHREVEPORT.



B. CONE-IN-CONE STRUCTURE SHOWN IN CALCAREOUS CONCRETION AT SLAUGHTERPEN BLUFF, SHREVEPORT.

Sabine uplift was more or less manifest in early Eocene or perhaps even late Cretaceous time. Desoto Parish, La., as well as Shelby, Panola, and Harrison counties, Tex., may have constituted an island in Claiborne time. The ferruginous, more or less brackish waters to the north of the island would naturally contain a very different fauna from that flourishing in the pure sea water to the south.

From what has already been said it will be seen that whereas the Claiborne group is poorly represented and seemingly of no special significance in the Caddo field its generally fossiliferous beds have been of great value during the past ten years in helping to determine the limits of the Sabine uplift in northwestern Louisiana and eastern Texas, an area whose economic importance is now beginning to be appreciated.

Wilcox ("Sabine") formation.—To the Eocene Wilcox are referred the greater portion of the beds forming the surface rocks over the Sabine uplift. In the bluffs about Shreveport, in many of the railway cuts from Shreveport to Mooringsport, and in the steep banks of Caddo and Soda lakes Wilcox beds are well exposed. (See Pl. XIII, *A*.)

The Wilcox beds are usually characterized, not only by a considerable amount of lignitic matter, locally in the form of seams several feet thick, but also by the number and size of the hard, gray, more or less calcareous concretions they contain. "Hard bowlders" are of common occurrence in Caddo well sections. As a rule they are not encountered below 450 feet, so in the general section of the field the dividing line between the Wilcox and Midway has been drawn at that depth. The appearance of these huge concretions in artificial excavations is well shown in Plate XIV, *A*. The cone-in-cone structure noticeable in many fragments from such concretions brought out by the drill in the Caddo field is shown in Plate XIV, *B*.

Although the sea was not far away during the deposition of the Wilcox beds in the Caddo field, as shown by the presence of a few Ledas and other small marine bivalves in Slaughterpen Bluff at Shreveport and by the selenitic particles in the lower portion of the bluff shown in Plate XIII, *A*, the presence of great numbers of dicotyledonous leaves and even thick beds of lignite and the marked cross-bedded structure of the sand beds point strongly toward local pond and subaerial deposition.

The Wilcox formation is not known to be of economic importance in the Caddo field. Certain layers are used for the manufacture of brick at Shreveport. Farther south, in the Dolet Hills especially, east of Mansfield, extensive beds of lignite occur in the Wilcox formation. Small quantities of oil have been found in this formation near Many. Brine from which salt has been manufactured occurs in the pervious Wilcox beds in the western part of the Sabine Parish.

Here the formation also contains extensive beds of lignite and in places beautifully preserved marine fossil shells. Along the roadside one-half mile west of Leigh, Tex., the sand beds of the Wilcox formation show not only most remarkable cross-bedded structure, but also concretion-like balls of semilignitic, semiasphaltic black matter, some of them a foot in diameter. (See Pl. XV, *A*.)

Midway formation.—The Midway formation, like the various Cretaceous formations described below, does not outcrop at the surface in the Caddo field. Owing to the lack of fossils in most of the Caddo wells in the beds above the Cretaceous, the limits of the Midway are here ill defined. The dark tough clays to a depth of perhaps 650 feet, in places containing a limestone layer around the 600-foot level, are provisionally referred to the Midway formation. Farther to the south in the Sabine uplift territory—for example, along the Texas and Pacific Railway for over a mile in the vicinity of Marthaville—*Ostrea sellæformis,* a very characteristic fossil of the basal Wilcox formation, occurs in great abundance. As the strata in that vicinity dip to the south, though but slightly, it is evident that Midway beds must occur at the surface over a considerable area to the north. Their geographic distribution has not yet been worked out. Fossils apparently of Midway age were found by the members of the Louisiana State Geological Survey at Rocky Springs Church, 6 miles southwest of Marthaville, ten years ago.[a] It would seem, therefore, that in this region the various formations occurring in the Caddo field should be about 450 feet nearer the surface than they are there.

CRETACEOUS SYSTEM.

Of the Cretaceous system only the upper portion, or Gulf series, occurs in the Caddo field, where it is represented by various formations, as indicated in the generalized section (fig. 17).

Arkadelphia clay.—The stiff black Arkadelphia clay, together with the Eocene Midway deposits, makes an excellent capping for the gas that occurs in great quantities in the sands below. Naturally, owing to the omnipresence of the thick Tertiary formations in this part of the State, there are no outcrops of the Arkadelphia clay in the Caddo field. These clays, however, are excellently displayed in bluffs and ravines in Arkansas just north of the Iron Mountain Railroad between Arkadelphia and Hope, where they are in places very fossiliferous.

Nacatoch sand.—The Nacatoch sand furnishes practically all the gas now being used from the Caddo field. About 800 feet may be taken as the average depth to the upper surface of this sand, though gas showings are sometimes found at several horizons before this depth is

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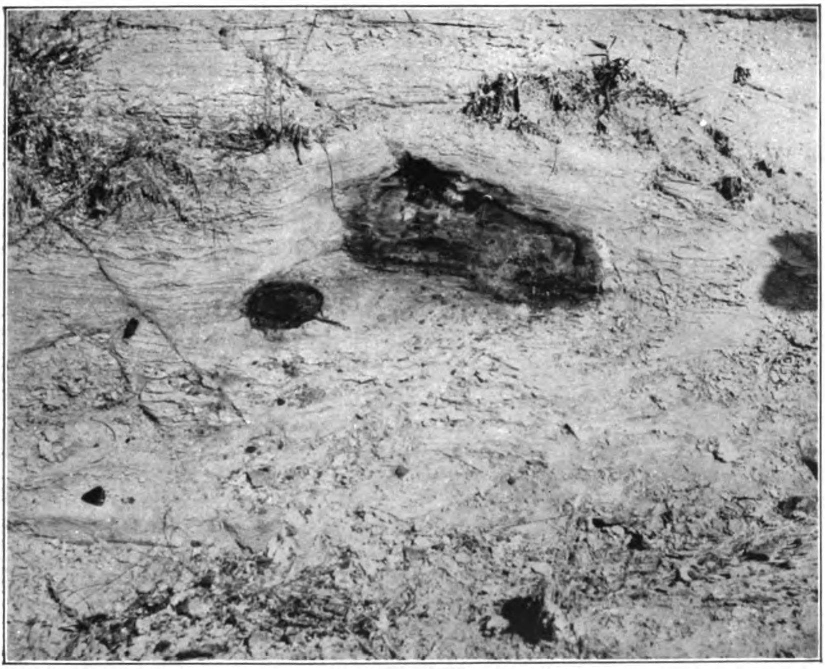
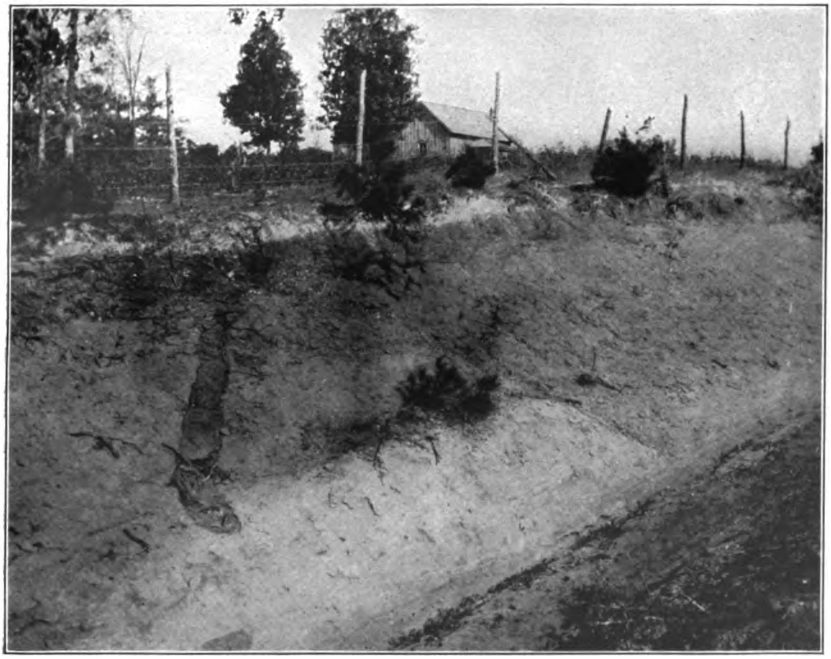
[a] Rept. Louisiana Geol. Survey for 1899, p. 63.



A. LIGNITE BALLS OR CONCRETIONS IN SANDS OF THE WILCOX ("SABINE") FORMATION, LEIGH, TEX.



B. EAST BANK OF CUT ON WASHINGTON-HOPE (ARK.) PUBLIC ROAD, 1½ MILES SOUTHEAST OF WASHINGTON.

Showing (below and to the left) Nacatoch sand with burrow of some Cretaceous reptile, now filled by later deposits (above and to the right).

reached. This sand is frequently styled the Caddo or the Shreveport gas horizon. It contains gas not only in the porous sandy layers, but also in the calcareous shelly seams. It is usually unnecessary, and in fact not good policy, to penetrate the sand for more than 2 or 3 feet. Enormous quantities of gas are obtained from it without accompanying salt water. These beds may be seen in surface outcrops in Arkansas, especially near Nacatoch, on Little Missouri River, and about and to the south of Washington. Along the Iron Mountain Railroad the Nacatoch sand is of great economic importance on account of the vast quantities of pure water it contains. Some layers or lenses of calcareous and quartzitic rocks among the sands are known in Arkansas as "water rocks."[a] Similar layers are encountered in the wells of the Caddo field.

Owing to the generally slight induration of the Nacatoch sand it quickly weathers into sand resembling ordinary superficial Quaternary material. This feature is admirably shown about Washington and along the highway to the south toward Hope. (See Pl. XV, *B*.) The calcareous matter of fossil remains soon leaches out through such porous sands, and fossils can rarely be seen in exposures of any considerable age. New cuts and deep ravines show that the original color of the Nacatoch beds is slightly greenish and that fossil remains have doubtless once been abundant in places where now no evidence of them appears. Particularly noticeable are long tubular ferruginous casts, doubtless once formed about roots or plant stems. Many of these can be traced for several feet. In some places whole cycad leaves have been incased in ferruginous matter and the form may be well preserved. In the uppermost layers, just beneath the Arkadelphia clay, great numbers of *Pectunculus* occur. (See Pl. XV, *B*.)

At Lewis, west of James Bayou and also east of Vivian, these sands furnish some oil, usually with large quantities of salt water. The oil is of a heavy grade, as may be seen by consulting No. 7 in the table of analyses of Caddo oil, page 131. At Powell, Tex., a similar oil is obtained apparently from this horizon.

Marlbrook marl.—The Marlbrook marl is decidedly more calcareous than any of the other formations so far described. Though composed largely of blue, chalky, somewhat glauconitic marls, it contains chalky layers locally 20 feet in thickness, found in the Caddo wells usually at a depth of about 1,150 feet. This is the "Saratoga" chalk member. The Marlbrook marl may be seen to good advantage about Marlbrook and Washington, Ark. It probably corresponds to the Taylor marl of the Texas sections farther west. A partial generalized section of the Austin region is given in the table following for comparison.

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[a] Veatch, A. C., Prof. Paper U. S. Geol. Survey No. 46, 1906, p. 27.

Partial generalized section of the Austin (Tex.) quadrangle.[a]

System.	Series or group.	Formation.	Kind of material.	Approximate thickness.
Quaternary.			Silt, sand, and gravel.	*Feet.* 0-90
Tertiary.	Neocene.	Uvalde.	Gravel.	0-70
	Eocene.	Lytton.	Clay, sand, and sandstone.	300+
Cretaceous (Upper).	Montana.	Webberville.	Black, slaty, bituminous clays with occasional harder layers. Contains green sand particles. Slightly impregnated with oil and gas. The oil-bearing formation of the Corsicana field.	400±
		Taylor.	Blue, unctuous marly clay ("joint clay") weathering into yellow subsoil and black soil.	540±
	Colorado.	Austin.	White chalk, with conchoidal fracture. Marly in upper portion.	410±
		Eagle Ford.	Blue clay and flaggy limestone. Oil traces.	30±

[a] Hill, R. T., and Vaughan, T. W., Austin folio (No. 76), Geol. Atlas U. S., U. S. Geol. Survey, 1902.

According to Adams, it is these beds that furnish the high-grade oil in the Corsicana field.

Austin group.—At depths ranging usually from 1,275 to 1,300 feet extensive deposits of chalk are encountered in the Caddo wells. They continue with slight clayey interruptions for more than 300 feet. These beds are the Annona chalk, the upper formation of the Austin group. Below are about 200 feet of fossiliferous chalky and marly clays with hard pyrite concretions known as the Brownstown marl and composing the lower formation of the Austin group. These various deposits, as they outcrop to the north in Arkansas, have been well described by Veatch in Professional Paper 46, previously cited. According to Gordon,[a] they are included in the Austin chalk farther west. The general relationship of these contiguous beds may be seen by consulting the generalized section given in figure 16.

Plate XVI, *B*, shows the appearance of the basal Annona chalk and upper Brownstown marl at White Cliff, Howard County, Ark. This bluff is on the left bank of Little River and is 130 feet high. About 1½ miles east of Clarksville, Tex., the Annona chalk forms the surface rocks and is well exposed in a field several acres in extent. This is the best locality the writer has seen for obtaining fossils from this formation. Plate XVI, *A*, shows the white appearance of the fields where such rocks crop out, and likewise the marked conchoidal fracture of these rocks.

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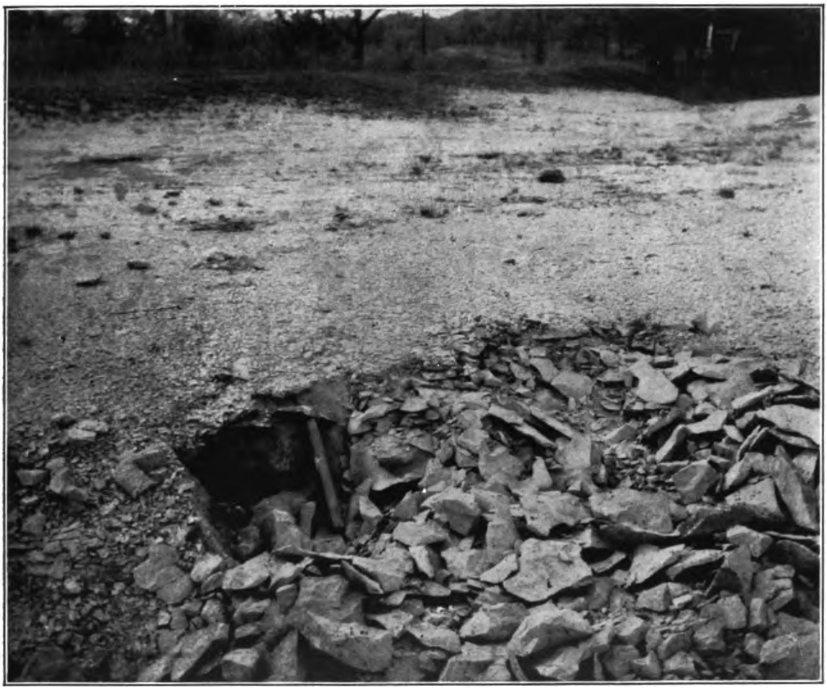
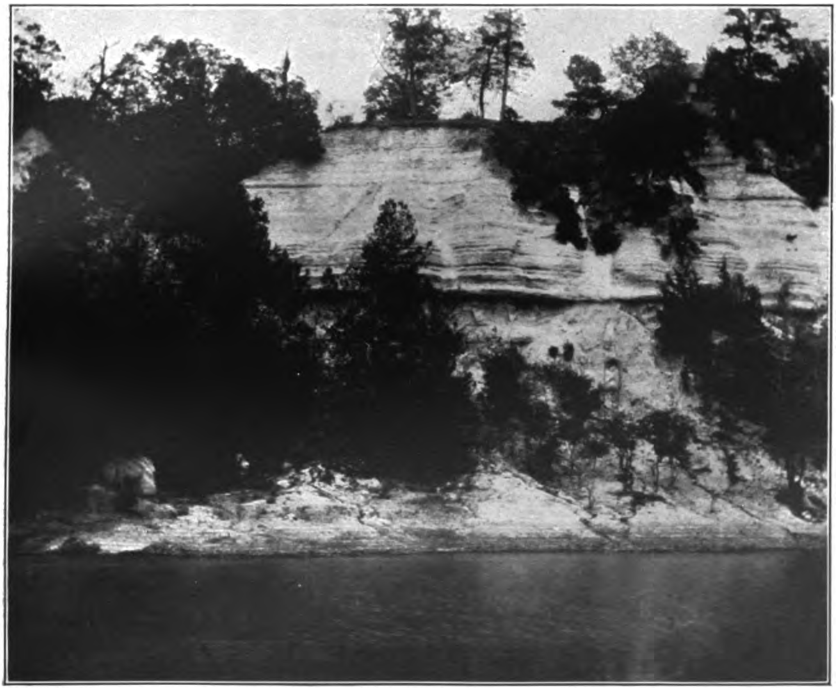
[a] Am. Jour. Sci., 4th ser., vol. 27, 1909, pp. 369-373.



A. ANNONA CHALK OUTCROP 1¼ MILES EAST OF CLARKSVILLE, TEX.

Showing conchoidal fracture.



B. ANNONA CHALK OVERLYING BROWNSTOWN MARL AT WHITE CLIFF, HOWARD COUNTY, ARK.

In two or three places in the Caddo field the Annona chalk has furnished a good quantity of high-grade oil from a depth of about 1,575 feet. Gas also is encountered in considerable quantity at about this depth.

Eagle Ford clay.—The Eagle Ford clay is characterized in its upper part by sandy layers, the "sub-Clarksville" sand of Veatch, or the Blossom sands of Gordon. In this report they are called the Blossom sand member. There are good indications of heavy oil from these sands at a depth of about 1,800 feet, though so far no paying wells have been obtained from this zone. The Eagle Ford clay, some 350 feet in thickness, is generally blue and tough and contains hard pyrite and limestone lenses. It serves the purpose of a cap rock for the oil and gas in the Woodbine sand below.

Woodbine sand.—The Woodbine sand consists of sand with clay layers, the former containing large quantities of oil, gas, and salt water. It is reached in the Caddo field usually at depths ranging from 2,140 to 2,300 feet, according to local stratigraphy and topography. So far this formation has been developed in the Caddo field only from Mooringsport to Caddo City. A number of wells between Oil City and Mooringsport have obtained light oil from practically the same depths as those at which the heavy oil is usually found in the Caddo field. (See table of analyses, No. 41.) The gas from this formation, though abundant, has not thus far been utilized to any extent.

STRUCTURE.

In studying the details of the Caddo field the reader should have constantly before him the index map here given as figure 16, which shows the location of areas covered by the Vivian, Pine Island, Oil City, and Mooringsport special maps (figs. 12 to 15) and of the lower section in figure 2 and the sections in figure 17 and Plates XVII, XVIII, and XIX. Figure 16 shows the depths to certain important strata along a north-south line from Texarkana to Shreveport. The lower section in figure 2 shows in greater detail that portion relating to the Caddo field proper. On Plate XVII are shown in detail some of the well sections on which the general deductions given in figure 17 are based. The records of certain wells along lines B–B and D–D of figure 16 are given in detail in Plates XVIII and XIX.

A study of the well records from Texarkana to Shreveport shows (1) a large syncline between Vivian and Texarkana, rendering the possibilities of obtaining good oil and gas wells between those places extremely meager; (2) a much smaller syncline between Vivian and Oil City, with an anticlinal fold in the syncline at Lewis; (3) an anticline just south of Vivian; (4) gently undulating, nearly horizontal

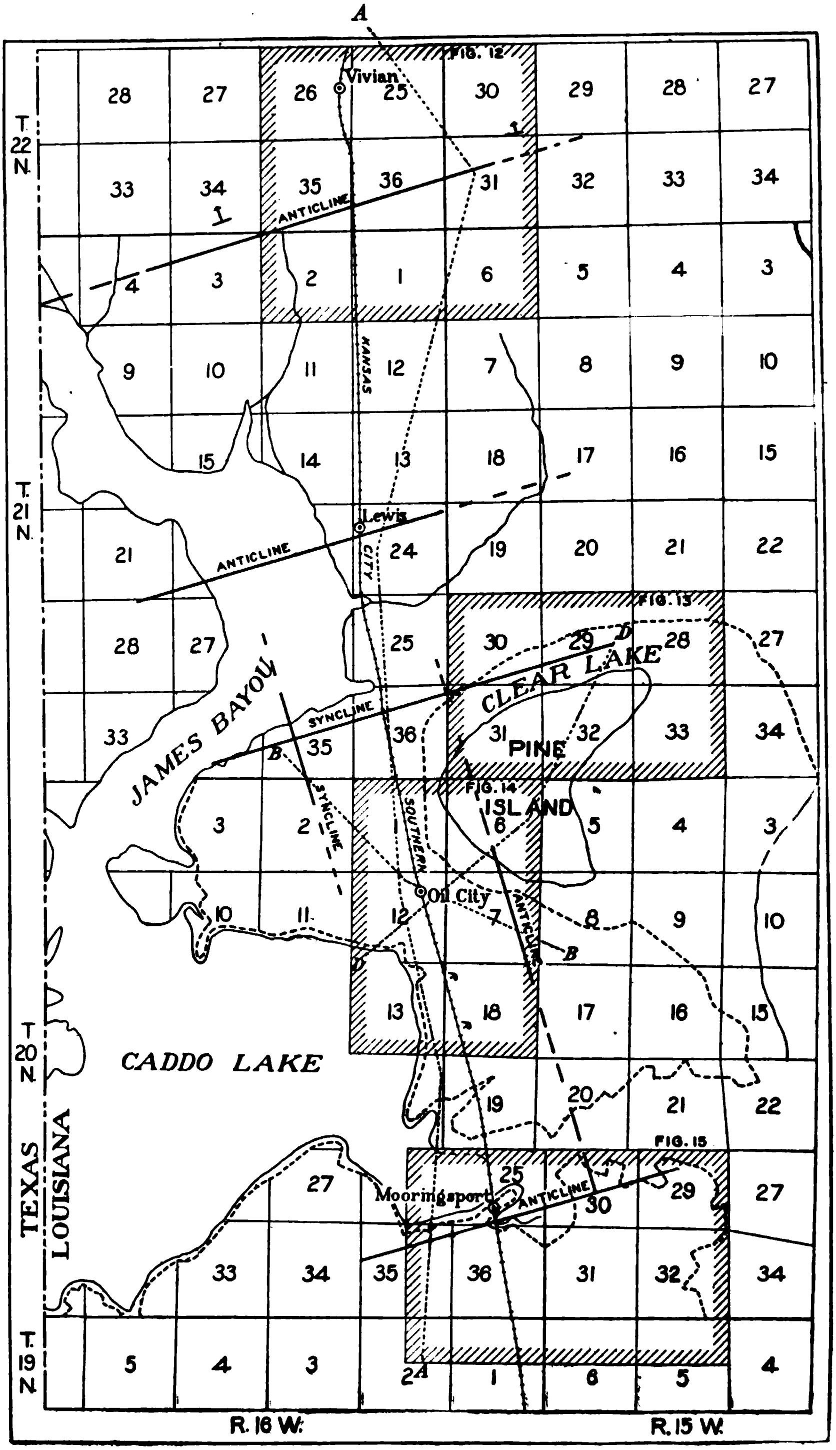
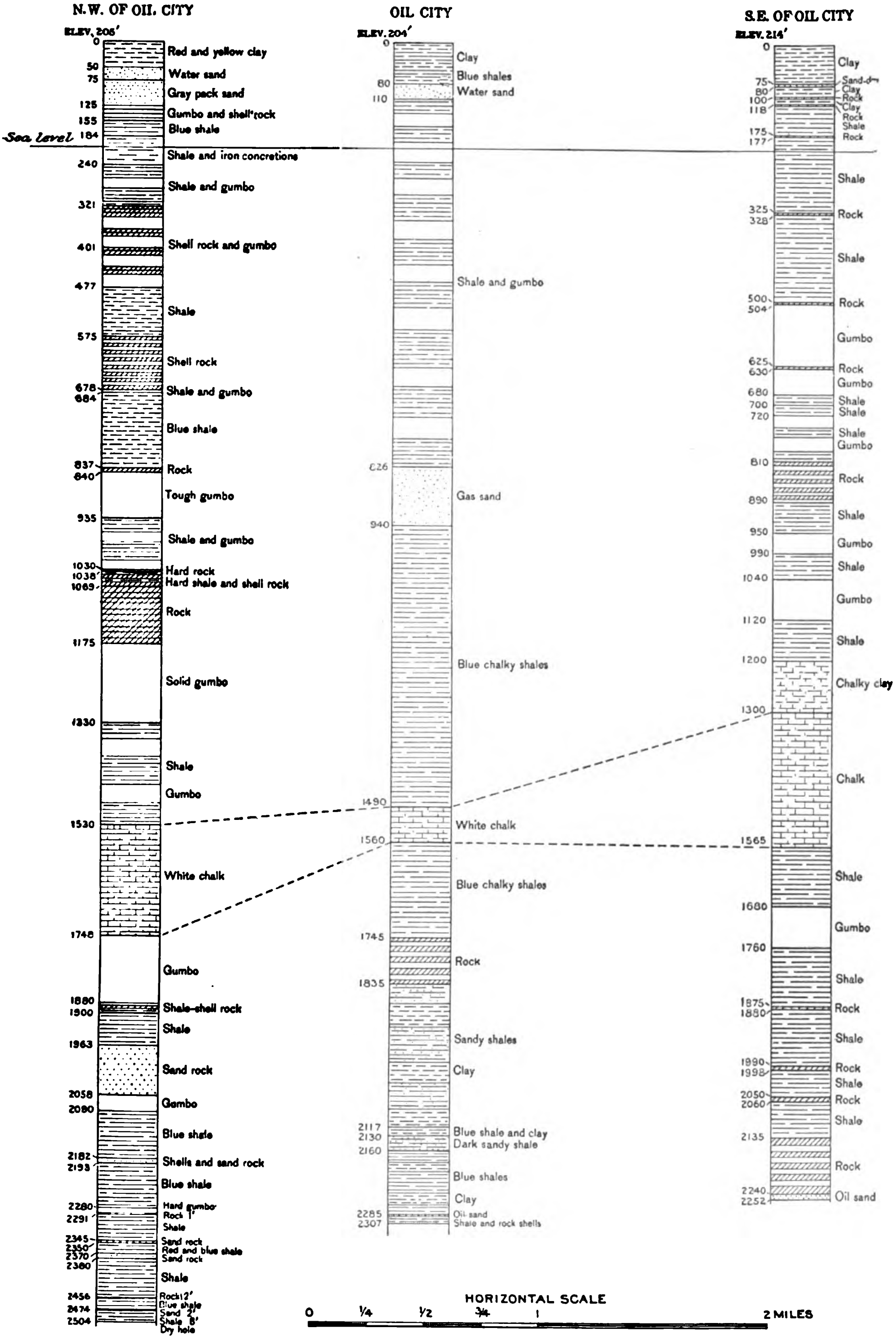


Figure 16.—Index map of the stratigraphy of the Caddo oil field.



DETAILS OF SECTIONS ALONG LINE B-B OF INDEX MAP OF CADDO OIL FIELD (FIG. 16).

strata between Oil City and Mooringsport; (5) a very slight syncline between Mooringsport and Shreveport.

In the Gulf regions, where the surface rocks are composed largely of unconsolidated material, in many places unfossiliferous, practically no means of determining the structure are at hand, except well records and surface relief. Therefore, some easily identifiable bed or beds must be chosen for general reference, and all others must be studied from this as a base. In the Caddo field there are two formations which are fairly uniform in character and which occur over the whole field. These are the Nacatoch ("Caddo gas") sand and the Annona chalk. Drillers are advised to note carefully the depths at which these formations are encountered and their thicknesses. Such careful notes will be of much more value in determining the structure at any locality in the field than loosely kept, poorly written logs of all the formations encountered.

In working out the relations of the oil and gas bearing strata, the formations just named were traced throughout the field, so far as was possible with the scanty data available, and the positions of the anticlines and synclines marked on the index map (fig. 16) were determined solely from the facts thus ascertained. Errors due to misinterpretation of well records, mistakes in log readings, etc., may have rendered the positions assigned to some of the anticlines slightly inaccurate, but in general the main structural features of the field are as indicated on the map.

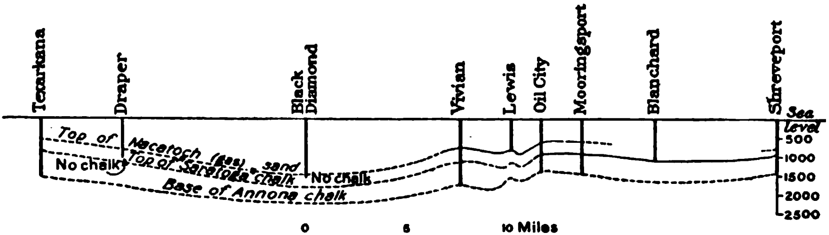


FIGURE 17.—Generalized north-south section from Texarkana through the Caddo oil field.

OCCURRENCE OF OIL AND GAS.

Four fairly well-defined oil and gas bearing zones are believed to be recognizable in the Caddo oil field. Of these at least two are found in practically every part of the field, although all vary more or less in thickness, composition, and yield from well to well. These zones are the Nacatoch ("Caddo gas") sand, the Annona chalk (porous in places), the Blossom sand member of the Eagle Ford clay, and the Woodbine sand. Of these, all but the Annona contain gas in considerable quantities and the Annona and Woodbine are in the main oil-producing beds. The beds of each zone are capped by thick deposits of clay or marl.

The Nacatoch is the zone from which practically all the gas now being used is obtained. The gas is for the most part clean and dry, but occasionally salt water works in and ruins a well. This stratum is usually found at a depth of 800 feet, more or less. At Lewis and farther west oil is found at this horizon.

In the Annona chalk there are here and there porous layers overlain by hard siliceous limestones that act as cap rock to confine oil in considerable quantities. One of the best wells in the field was brought in from this zone, but it furnishes very few producing wells. The first well in the field was drilled into the Annona chalk and was a producer for a short time.

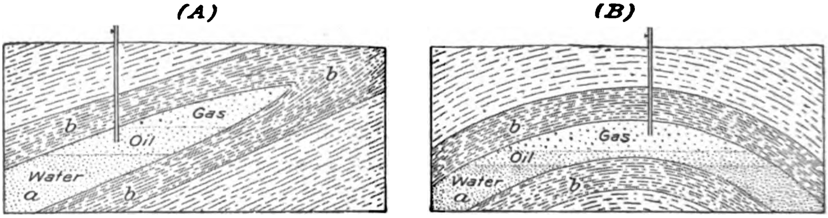


Figure 18.—Types of oil and gas reservoirs. *A*, Inclined bed of sandstone (*a*) sealed in by shales (*b*) but somewhere in communication with water under hydrostatic pressure. *B*, Sandstone bed (*a*) interstratified with impervious beds (*b*) and forming an arch or anticline, somewhere in communication with water under hydrostatic pressure.

The Blossom sand member, though containing gas in large quantities, has as yet been little developed, owing to the ease with which gas is obtained from the shallower Nacatoch sand. The Brownstown marl forms an excellent cap rock for this member, and if salt water does not drown out the sand it will provide an admirable reserve supply of gas.

The lowest zone, or Woodbine sand, contains oil in abundance, and it is at this horizon that most of the oil is being obtained. Most of the wells producing from this zone range in capacity from 25 to 500 barrels daily, and one or two wells are reported to be making from 1,000 to 1,200 barrels.

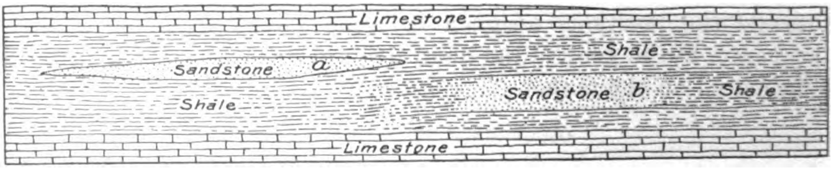


Figure 19.—Sketch illustrating disappearance of sandstone beds. *a*, Lenticular sandstone which disappears by thinning out; *b*, sandstone which grades into shale.

The oil and gas are obtained from the folds in the Cretaceous beds and occur in dome-shaped, anticlinal, or inclined sandstone reservoirs sealed in by clay and gumbo. (See fig. 18.) The fact that the logs of near-by wells differ materially may best be illustrated by an ideal sketch of the occurrence of sandstones in a shale formation.

In figure 19 the sandstone lettered *a* is lenticular in shape and thins out, disappearing entirely from the section and having no equivalent, and the sandstone lettered *b* grades over into a shale which is its equivalent. Sandstone *a* is apparently the result of sedimentation at a time when only sand was being deposited. Sandstone *b* apparently represents a period of sedimentation in which both sands and muds were being laid down, according to the local variation in the strength of the currents which assorted the material.

OIL OF THE CADDO FIELD.

PRODUCTION.

The following figures, taken from the Oil Investors' Journal, give a very fair idea of the production of the Caddo field: 1906, 4,650 barrels; 1907, 48,266 barrels; 1908, 513,504 barrels.

The same journal furnishes the following estimates of daily production at semimonthly intervals during the year from May, 1908, to May, 1909:

Daily production of oil in the Caddo field at semimonthly intervals, 1908-9.

1908.	Barrels.	1908.	Barrels.
May 15	1,450	December 15	3,750
May 31	2,010	December 31	3,000
June 15	2,200	1909.	
June 30	2,285	January 15	3,275
July 15	2,000	January 31	2,700
July 31	1,700	February 15	2,100
August 15	2,000	February 28	2,580
September 15	2,000	March 15	3,000
September 30	4,500	March 31	2,850
October 15	2,700	April 15	3,100
October 31	3,600	April 30	2,930
November 15	3,100	May 15	2,650
November 30	1,900	May 31	3,100

The production of the Caddo field for 1909 was about 1,000,000 barrels. This means that in oil alone it somewhat surpassed the maximum output of the Corsicana and Powell fields.

Concerning the probable amount of oil in the Caddo field and its manner of occurrence, no reason has appeared for modifying the views expressed by the writer in the Oil Investors' Journal, November, 1908:

> It is a most important fact to note that this field is not one of extreme local concentration. It has nothing in common with Beaumont or Jennings, but everything, save age, in common with those of western Pennsylvania, West Virginia, Ohio, and Illinois. Its vastness speaks well for both quantity of oil and gas and the longevity of the field.

The comparative slowness of development in the Caddo field has frequently been commented upon. It is due to the fact that the earlier, shallow wells were troubled with heavy gas pressure and furnished little oil. The first really successful deep wells produced heavy oil.

Richardson No. 2, on the Etcheson and Mayfield land, in sec. 32, T. 21 N., R. 15 W., was a fine producer at the start, being rated at 300 barrels an hour when it came in October 25, 1908. It went to mud and water and in a day or so sanded up. September 6, 1908, the Caddo Gas and Oil Company's well No. 1, on the Gilbert tract, came in with a daily production of 400 barrels of high-grade oil. (See table of analyses.) Producers' Nos. 1 and 2, on the Lane tract, in sec. 18, T. 20 N., R. 15 W., were also soon brought in, showing high-grade oil in greater quantity than the well on the Gilbert tract. Similar high-grade oil was known to exist on the Hostetter place east of Mooringsport for some time before the exciting days of the completion of Guffey-Hostetter No. 2. It was rumored that this was a 10,000-barrel well when completed in December, 1908. Shipments from Mooringsport, however, soon showed that it was yielding about 3,000 barrels daily. On the whole, Producers' No. 2, on the Lane tract, has been the best well in the field. It commenced flowing in September, 1908, at a reported rate of nearly 1,000 barrels, and as late as March 1, 1909, was still flowing about 500 barrels daily.

Good quantities of high-grade oil have been produced from the "deep sand" (Woodbine) in secs. 13 and 18 about a mile south of Oil City and in sec. 30 east of Mooringsport. Other localities furnish a lower-grade oil, often with much salt water, from this zone.

Local porous lenses in the Annona chalk in sec. 1, three-fourths of a mile northwest of Oil City, may furnish a fair supply of high-grade oil.

Small quantities of heavy oil are found in the Nacotoch sand west of James Bayou, in secs. 27 and 22. Three wells furnish about 85 barrels daily; the Rogers wells, at Lewis, 30 barrels; the Vivian Oil Company's three wells in sec. 36, near Vivian, 150 barrels.

Until the summer of 1908 practically all oil shipments had to be made by the Kansas City Southern Railway. Loading racks were constructed at Caddo, Oil City, and Mooringsport. A 6-inch pipe line has been constructed from the field to Grigsbys Island, south of Shreveport. This will permit railway shipments over at least half a dozen different roads as well as water transportation on Red River. Doubtless, too, the field will be connected with the Standard pipe line from Oklahoma in the near future.

ANALYSES.

The samples analyzed as shown below were collected in the Caddo field in December, 1908. They well represent the geographic extremes of the field from Mooringsport to Vivian, and from a locality west of Oil City to sec. 10, 4 miles to the east. They also show the character of oil from the "shallow" sands at Vivian; the Annona chalk horizon; the 1,600-foot stratum west of Oil City (sample No. 4); and the Woodbine "deep" oil, heavy (Nos. 5, 6, 9, 10) and light (Nos. 1 and 2).

January 21, 1909, D. T. Day, of the United States Geological Survey, wrote as follows concerning the oil samples sent in for analysis:

The analyses of these oils were very difficult on account of the unusual proportion of water contained in several of them. The results are rather remarkable in several other respects. For example, the burning oil is of unusually low specific gravity, rendering it more suitable for burning in lamps than other oils in Louisiana or the oils from Texas. There is practically no sulphur in the oil.

The water in the oil is held rather obstinately, because it is intimately emulsified with hydrated clay, which also gives off its water at about 160°. In one case, No. 8, this hydrated clay amounted to 0.7 per cent of the sample. * * * The amount of paraffin wax is considerable. Except for the unusual proportion of water, which can be removed in ordinary practice quite easily by the use of steam, the oils are very satisfactory.

Analyses of oils from Caddo field, Louisiana.

No. of specimen.	Location of well.	No. of well.	Depth of well (feet).	Physical properties.			
				Gravity at 60° F.			
				Specific.	Baumé (°).	Color.	Odor.
La. 1	Hostetter farm, Mooringsport	1	±2,210	0.8187	41.0	Black	Like Okla.
2	Caddo Oil and Mineral Co., Gilbert lease, NE. ¼ NE. ¼ sec. 13, T. 16 N., R. 20 W.	1	±2,245	.8264	39.4	...do	Do.
3	Frank Filer lease, NW. ¼ SE. ¼ sec. 7, T. 15 N., R. 20 W.	1	2,250	.9211	22.0	...do	Do.
4	Old Caddo Oil and Gas Co., E. K. Smith's land.	1	1,620	.8723	30.5	...do	Do.
5	Richardson well, NW. ¼ NW. ¼ sec. 7, T. 15 N., R. 20 W.	2	2,245	.8929	26.8	...do	Do.
6	Black Bayou Oil Co., SW. ¼ sec. 10, T. 15 N., R. 20 W.	1	2,220	.9150	23.0	...do	Do.
7	Dawes well, 1 mile southeast of Vivian, NW. ¼ NE. ¼ sec. 36, T. 22 N., R. 16 W.	1	1,050	.9253	21.3	...do	Do.
8	Caddo Oil and Gas Co., E. K. Smith's farm.	4	2,280	.9211	22.0	Brown	Do.
9	Producers' Oil Co., NE. ¼ NW. ¼ sec. 12, T. 20 N., R. 16 W.	6	....	.8889	27.5	Black	Do.
10	Richardson Oil Co., NE. ¼ NW. ¼ sec. 32, T. 15 W., R. 21 N.	4	2,132	.9121	23.5	...do	Do.

No. of specimen.	Distillation by Engler's method.							Sulphur.	Paraffin.	Asphalt.	Remarks.	Geologic horizon, by G. D. Harris.
	Begins to boil at (°C.).	By volume.										
		To 150° C. (cubic centimeters).	150°-300° C.		Residuum.		Total (cubic centimeters).					
			Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.						
La. 1	138	3.0	55.0	0.7778	40.4	0.8866	98.4	0	1.70	0.09	....	Woodbine.
2	136	1.5	49.0	.7778	49.1	.8805	99.6	0	5.30	.25	....	Do.
3	200	......	12.0	.8510	82.9	.9061	100.9	0	7.78	.91	Contains water	Do.
4	210	......	28.0	.8299	69.5	.8895	97.5	0	7.32	.14	.....do	Austin.
5	173	......	20.0	.8408	79.0	.9061	99.0	0	5.29	.50	.....do	Woodbine.
6	210	......	18.0	.8450	81.2	.9138	99.2	0	......	.24	.....do	Do.
7	205	......	17.0	.8406	85.9	.9302	102.9	0	......	.22	.....do	Nacatoch.
8	200	......	14.0	.8142	59.0	.8974	73.0	0	3.64	.34	20 per cent water, 0.7 per cent clay.	Woodbine.
9	220	......	18.0	.8406	79.4	.9003	97.4	0	4.78	.64	Much water	Do.
10	220	......	16.5	.8713	66.6	.9241	83.1	0	......	.54	.....do	Do.

JAMES BAYOU DEVELOPMENTS IN 1909-10.

By David T. Day.

Recent developments on the west side of the Caddo field have entirely changed the economic conditions since this report was submitted for publication, and a brief review of these developments is necessary in order that the conditions in the Caddo field may be clearly understood as they exist at the present time. During July, 1909, the J. C. Trees Oil Company, operating on the Stiles tract, in sec. 17, T. 21 N., R. 16 W., began to deepen its well No. 4, located on the western edge of the section. This work was delayed by many causes and the well was reported as shut down November 1, 1909, after having been drilled from 1,100 to 2,200 feet in depth in an experimental effort to test the deep sands of this region corresponding to the Woodbine sand, which is productive 5 miles to the southeast. On November 12 this well had been continued below 2,300 feet and began to yield oil at the rate of over 2,000 barrels per day before the drill stem had been removed from the hole. After a month the production dropped to half its initial rate; but gradually increased again to nearly 3,000 barrels per day and has continued, varying between 1,000 and 2,000 barrels, up to the present time. The Gulf Pipe Line Company, owning a large tract of land 2½ miles southwest of the Trees well No. 4 referred to above, at once began to drill 700 feet over the line in Texas, the well being designated as No. 1, Burr tract. In April, 1910, at a depth of 2,225 feet, this well began to flow by heads 2,000 barrels a day. The oil is 43.6° Baumé in gravity, and gives the following analysis:

Analysis of oil from Gulf Pipe Line Company's well "No. 1, Burr tract."

	Cubic centimeters.	Specific gravity.
Distillation by Engler's method.		
Begins to boil at 95° C.		
To 150° C	15	0.7275
150°-300° C	47	.7770
Residuum	40	.8739
	102	....

	Per cent.
Paraffin	7.02
Asphalt	7.02
Unsaturated hydrocarbons:	
Crude	12.8
150°-300° C	5

After several interruptions in the flow this well is still making nearly 2,000 barrels per day. The Producers Oil Company immediately began developments in the territory between Guffey's No. 1, Burr tract, and the Trees well No. 4, obtaining a well larger than any of the preceding ones (estimated at 11,000 barrels) in sec. 27, T. 21 N., R. 16 W. This was at once offset by a well (No. 9, Stiles tract) 95 feet west, which showed a greater yield than the Producers well near by, but the production of each well was influenced by the other. A well northeast of Trees No. 4, sunk by the Producers Company, showed salt water, and this, with several dry holes brought in on the northwest side of the developed territory, has led to the general belief that the field is narrow to the northeast, broadening to the southwest. Late in June the Producers Oil Company brought in its No. 6, in sec. 33, T. 21 N., R. 16 W., and it proved a larger producer than any of the others. Claims have been made for this well at 12,000 to 20,000 barrels, but so far as is known its actual yield has not yet been definitely tested, on account of a leaking nipple and a subsequent fire. The well was struck by lightning June 19 and was skillfully extinguished June 21. The depths at which the pay sand has been encountered in this James Bayou pool vary from 2,207

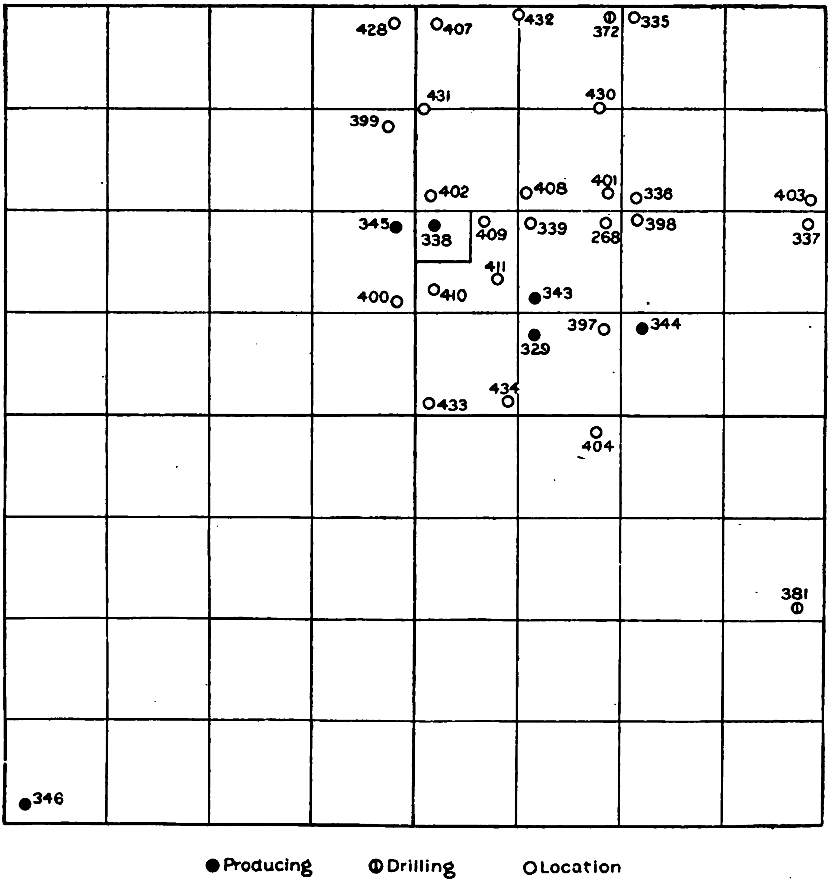


FIGURE 20.—Map of sec. 33, T. 21, R. 16, showing location of wells.

feet to somewhat more than 2,300 feet. The thickness of the oil-bearing sand has not been determined. Salt water is reported at 2,351 feet. Little can be said as to the prospective life of these wells, although all of them have kept up their high production for a surprisingly long time. The field is being prospected for more than 5 miles to the west in Texas, and generally to the southwest. The Standard Oil Company has connected its Baton Rouge pipe line with the Trees wells, while the Producers and Guffey interests are caring for their production through tank-car shipments from their tank stations in Oil City. The Guffey Company has begun a 6-inch pipe line to connect at Lufkin, Tex., with its main lines to Beaumont.

Considerable interest is being shown in the Vivian extension north of the Caddo field, where a few wells of 500 barrels a day have been developed from the shallow sand. The total production in the Caddo field on July 1, 1910, was more than 30,000 barrels a day.

The following data of producing wells cover new development in Louisiana and East Texas:

MARION COUNTY, TEX.

No. 305: Gulf Refining Company, Burr No. 1, depth 2,244 feet, set 2,230 feet, 6-inch casing, flowing 1,500 to 1,800 barrels of oil a day (May 10, 1910).

No. 324: Gulf Refining Company, Burr No. 2, set 1,040 feet 8-inch casing. Drilled in July 17, 1910, pumping heavy mud in hole; closed gate and moved rig. Had some showing, but did not bail; 6-inch casing set.

LOUISIANA.

Sec. 5, T. 20 N., R. 16 W.—No. 351: Gulf Refining Company, on Reaves; came in flowing on June 2, 1910, making 500 barrels.

No. 354: Gulf Refining Company, Mason No. 1; came in flowing by heads May 30, 1910, making probably 800 barrels. Set 1,140 feet 8-inch casing. Sealed in 6-inch. Set 4½-inch casing. Flowing 550 barrels (June 2, 1910).

Sec. 33, T. 21 N., R. 16 W. (see fig. 20).—No. 346: Trees Oil Company, No. 14; came in flowing approximately 1,200 to 1,500 barrels; depth approximately 2,200 feet.

No. 345: Trees Oil Company No. 12; came in flowing about 1,500 barrels with drill pipe in hole; flowing approximately 600 barrels (July 5, 1910).

No. 338: Sun Company No. 5; flowing 400 barrels July 7, 1910.

No. 343: Producers Mason No. 2; flowing July 7, 1910; small well.

No. 329: Busch-Everett Company; set 2,240 feet 6-inch casing; set 4-inch casing at 2,337 feet; showing at 2,205 feet; came in about June 17, 1910, flowing 600 barrels of oil, 75 barrels of water (estimated).

No. 344: Producers Oil Company, Levee Board No. 6; flowing June 17, 1910; struck by lightning June 20, 1910; good for 15,000 barrels.

Sec. 28, T. 21 N., R. 16 W.—No. 307: Trees Oil Company; came in 10 a. m., June 1, 1910, flowing 500 to 600 barrels by heads; very little gas pressure; will drill deeper.

Sec. 27, T. 20 N., R. 16 W.—No. 235: Trees Oil Company No. 4; made test at 1,900 feet; got salt water; set 4-inch casing at 2,140 feet; came in flowing 2,500 barrels of oil, 42° gravity, no water; fell off to 600 barrels of oil about December 29, 1909; blew loose and made 1,000 barrels; flowing 1,200 barrels January 22, 1910; flowing 2,500 barrels February 23, 1910; flowing 85 to 90 barrels per hour May 13, 1910.

No. 287: Trees Oil Company, came in flowing 2,000 to 3,000 barrels, strong gas pressure, depth 2,300 to 2,350 feet; flowing 1,000 barrels March 26, 1910; flowing 60 barrels per hour May 13, 1910.

No. 165: Trees Oil Company, salt-water well.

Nos. 138, 173, and 204: Trees Oil Company, making about 35 to 40 barrels oil per day.

No. 309: Trees Oil Company, No. 9; came in flowing 6,000 to 7,000 barrels 41° gravity oil; very strong gas pressure; came in about May 9, 1910; flowing 4,500 to 5,000 barrels up to May 25; flowing 1,000 barrels May 31; drilling deeper; flowing 1,200 barrels June 10, 1910.

No. 297: Producers Oil Company; flowing 1,500 barrels April 26, 1910; flowing 100 barrels an hour May 1, 1910; quit flowing when Trees Oil Company No. 309 came in; drilled deeper; well started flowing again after first bailer was run and flowed for probably five minutes, when it choked off again; washed out with oil May 13, 1910; bailing May 16; came in flowing about 8,000 barrels (reported); No. 309 making 5,000 to 6,000 barrels; flowing 6,000 barrels June 10; flowing 7,500 barrels June 27; flowing 7,000 barrels July 5, 1910, and showing some roily oil, probably on account of the effort to bring in No. 313 just south of it.

No. 314: Producers Oil Company; bailed April 29, 1910; got some salt water with very little showing of oil; drilling deeper; used 133 joints of 2-inch extra heavy drill stem; plugging off salt water May 6; flowing with gas, showing some oil, July 5, 1910.

Sec. 31, T. 22 N., R. 15 W.—No. 255: Vivian Oil Company; came in September 29, 1909, flowing 100 barrels of oil, 300 barrels of water; 300 feet of 8-inch, 1,050 feet of 6-inch casing; flowing through 6-inch casing; flowing 450 to 500 barrels of oil, 3,000 barrels of water, October 17, 1909; flowing 200 barrels, February 5, 1910.

No. 285: Vivian Oil Company; blowing dry gas with slight spray of oil January 2, 1910; blew in January 3, flowing probably 2,000 barrels of salt water with 60 to 75 barrels of oil, gradually increasing; flowing 125 to 150 barrels of oil February 1, 1910.

No. 383: Gulf Refining Company; abandoned.

No. 269: Busch-Everett, Pitts No. 1; 1,046 feet deep; showing of oil; capped.

Sec. 30, T. 22 N., R. 15 W.—No. 312: Gulf Refining Company; flowing 30 to 40 barrels of oil, no water; very weak gas pressure, March 7, 1910; flowing 20 barrels May 28, 1910.

No. 328: Gulf Refining Company.

No. 286: Sun Company; flowing 180 barrels.

No. 298: Sun Company; gas well.

No. 362: Sun Company; flowing with gas, 50 barrels.

No. 412: Sun Company; flowing 200 barrels.

No. 366: Sun Company; flowing 250 barrels.

No. 363: Sun Company; flowing 100 barrels.

No. 267: Caddo Gas and Oil Company; small oil well; capped.

No. 387: Caddo Gas and Oil Company; flowing 800 barrels.

No. 364: Caddo Gas and Oil Company; flowing 500 barrels.

No. 415: Caddo Gas and Oil Company; flowing approximately 1,000 barrels June 28, 1910.

Sec. 29, T. 22 N., R. 15 W.—No. 311: Producers Oil Company; flowing approximately 75 barrels.

Sec. 23, T. 22 N., R. 15 W.—No. 320: Arkansas Gas and Development Company; flowing about 250 barrels of roily oil, about 40 to 50 per cent BS.; very little gas pressure, May 12, 1910.

GAS IN THE CADDO FIELD.

PRODUCTION.

Gas in immense quantities seems to have a more general distribution than oil in the Caddo field. For years gas has been obtained from the Nacotoch sand beneath Shreveport, but in the last five years gas has been found in enormous quantities in the region from Mooringsport north to Vivian and from points west of James Bayou east to Dixie.

This field first attracted the attention of the general public by its famous burning gasser. Producers' No. 2 blew out in May, 1905, with terrific force. The gas caused the waters in and about the well to assume a boiling, churning motion that loosened the earth for a distance of some yards, so that the derrick and machinery were engulfed in a mass of mud. On June 18 the gas was lighted, and for five months thereafter this well was known as the "geyser," attracting visitors from all parts of the country. Maj. Frank M. Kerr visited the place on behalf of the State to see what might be done to check the waste of gas, and in his report to the governor says in part:

> On the day of this visit the well presented a scene of magnificent energy and surprising spectacular effect. A basin or bowl of water some 250 feet in diameter had resulted from the action of the escaping gas and the roll of the waves from the mouth of the orifice toward the rim of the basin, like waves on a sea beach in stormy weather, from the center of which leaps a flame some 30 feet in diameter and equally high. This, with the monster upheaval of water and leaping of spray, presented a spectacle which might readily have been likened to the display of a prismatic fountain of unusual magnitude and superb effects.

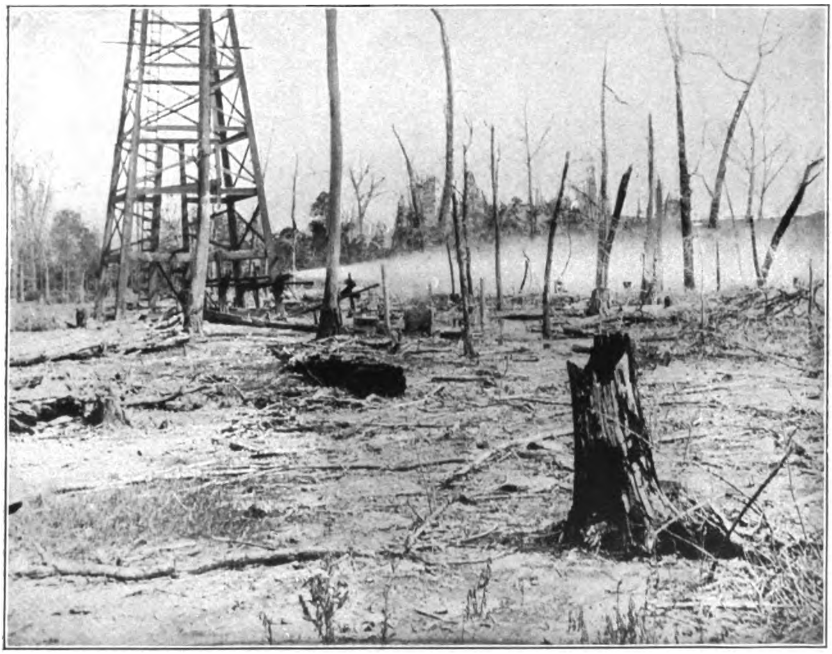
Plate XX, *A*, shows the present appearance of this locality.

Producers No. 3, in the same vicinity, a few hundred yards west of Oil City, repeated the history of No. 2 in a somewhat milder form, during the latter part of 1905 and the early part of 1906.

The Caddo Gas and Oil Company's well on the Gilbert tract, in the eastern part of section 13, perhaps 200 yards west of the Kansas City Southern Railway tracks, or 1¼ miles south of Oil City, has had a remarkable history as a "geyser," or "wild well." After a period of over three years of constant eruption it still appears vigorous, as shown by Plate XXI, *A*. The description of Producers No. 2 given above fits this well with but slight modifications of detail. When the gas is lighted the heat of the flames raises the water to the boiling point. The tumbling and seething of the waters, the roar of the escaping gases, and the light and heat of the leaping flames produce an impression long to be remembered. The details of the boiling, red, muddy waters appear more clearly when the gas is not lighted, as shown in the illustration. When the gas is lighted, the flames cover the greater part of the dark "boiling" space shown in the central part of the illustration and reach an equally great height.

A. SCENE OF THE FIRST FAMOUS BURNING GAS WELL (PRODUCERS NO. 2) IN THE CADDO FIELD.

Photograph taken in the fall of 1908.



B. PRODUCERS WELL NO. 1, CADDO FIELD, BLOWING SALT-WATER SPRAY AND GAS A DISTANCE OF SEVERAL HUNDRED FEET.

Photograph taken December, 1908.

Another famous burning or "wild" well was that known as Dawes Trustee, No. 1, in the NE. ¼ SW. ¼ sec. 7, T. 20 N., R. 15 W. A brief history of the well is given on page 143 in the list of wells in the Caddo field. This well alone probably wasted about 40,000,000 cubic feet of gas daily between the middle of May, 1908, and February 12, 1909. (See Pl. XXI, *B*.)

The daily waste in the Caddo field during the latter part of the year 1908 was estimated as about 70,000,000 cubic feet.

In June, 1907, the Oil Investors' Journal listed the producing gas wells of the Caddo field as follows:

Producers Oil Company, Heilperin & Liebman, sec. 6, 2,200 feet, 2½-inch hole, 8,000,000 gasser, rock pressure 900 pounds.
McGuire No. 1, Barron, sec. 17, 802 feet, 20,000,000 gasser.
McGuire & Evans No. 2, sec. 18, 812 feet, 15,000,000 gasser.
McGuire & Evans No. 3, sec. 18, 2,000 feet north of No. 2, 15,000,000 gasser.
McGuire No. 4, Barnhardt, sec. 21, 812 feet, 15,000,000.
McGuire No. 5, Huckaby, sec. 17, 823 feet, 25,000,000.
McGuire No. 6, Walter Crawford, sec. 15, 1,500 feet north of McGuire No. 4, 15,000,000.
McGuire No. 7, Barnhardt, sec. 21, half mile east of McGuire No. 4, 795 feet, 15,000,000.
J. B. & W. S. Atkins, NE. ¼ NW. ¼ sec. 18, Evans, 15,000,000.
J. M. Guffey Petroleum Company, No. 1, Hostetter, 810 feet, 15,000,000.
Dixie Oil and Pipe Line Company No. 2, southeast part of Pine Island, 800 feet, small gasser.

Since June, 1907, the following gas wells have been announced in the Journal:

McGuire No. 9, school land, sec. 16, 805 feet, 20,000,000.
Cullinan & Jolly No. 1, 810 feet, 25,000,000.
McGuire No. 10, school land, sec. 16, 285 feet, 20,000,000.
Dixie 2, Glassell, 5½ miles east of Mooringsport, a gasser, sec. 36.
McGuire No. 11, school land, gasser, 25,000,000.
Producers No. 2, Murray, NW. ¼ SW. ¼ sec. 7, T. 20 N., R. 15 W., gasser.
Caddo Gas and Oil Company No. 1, Pardue (Vivian), 2,500,000.
Caddo Gas and Oil Company No. 9, Mooringsport, 8,000,000.
Caddo Gas and Oil Company No. 10, Mooringsport, 10,000,000.
Caddo Gas and Oil Company No. 11, Smith, 15,000,000.
McCann & Harper No. 1, Pitts, NE. ¼ NW. ¼ sec. 31, T. 22 N., R. 15 W. (Vivian), 50,000,000.
Busch-Everett No. 1, Douglass, SW. ¼ sec. 30, T. 20 N., R. 14 W. (Dixie), 10,000,000, dry at 2,330 feet.
Busch-Everett No. 1, Vivian Mercantile Company, sec. 29, T. 22 N., R. 15 W., 60,000,000, 8-inch hole, depth 1,040 feet.

UTILIZATION OF CADDO GAS.

The amount of gas escaping at the surface near the site of the original Savage & Morricell wells is said to have been sufficient when collected to furnish heat and light for a frontiersman's cabin.

Producers No. 1, a few hundred yards northwest of Oil City, now blowing salt water and gas (Pl. XX, *B*), was the first well to furnish a large supply of gas for drilling purposes in the field. The many new "gassers" soon brought in naturally suggested the desirability of utilizing the gas outside of the field. The Citizens Oil and Pipe Line Company, with a capitalization of $3,000,000, put down the first pipe line to Shreveport in the fall of 1905 and the spring of 1906, supplanting gas in the Shreveport lines on May 20, 1906. The price of gas for domestic purposes was established at 35 cents a thousand and for manufacturing purposes at half that rate. A second pipe line was laid in 1907, and an 8-inch line was carried as far north as Texarkana in the latter part of 1908, 47 miles being completed November 27, 1908. The price to ordinary consumers taking from this line was fixed at 27½ cents a thousand; for manufacturing purposes at 10 cents. Dixie began to use gas from its wells near by in the fall of 1908, and started a line northward to Belcher.

By far the greatest project for utilizing Caddo gas is that undertaken by the Busch-Everett syndicate, of St. Louis, which has entered into a contract to furnish New Orleans with natural gas within less than two years and a half from 1909. To lay a 16, 20, or 24 inch pipe successfully for a distance of somewhat over 400 miles, crossing bayous, swamps, and Atchafalaya and Mississippi rivers, is certainly a considerable undertaking, involving doubtless an expenditure of $10,000,000. Prices for gas in New Orleans will vary from 35 to 45 cents a thousand, in accordance with the amount used.

Even St. Louis has been mentioned as a possible market for Caddo gas.

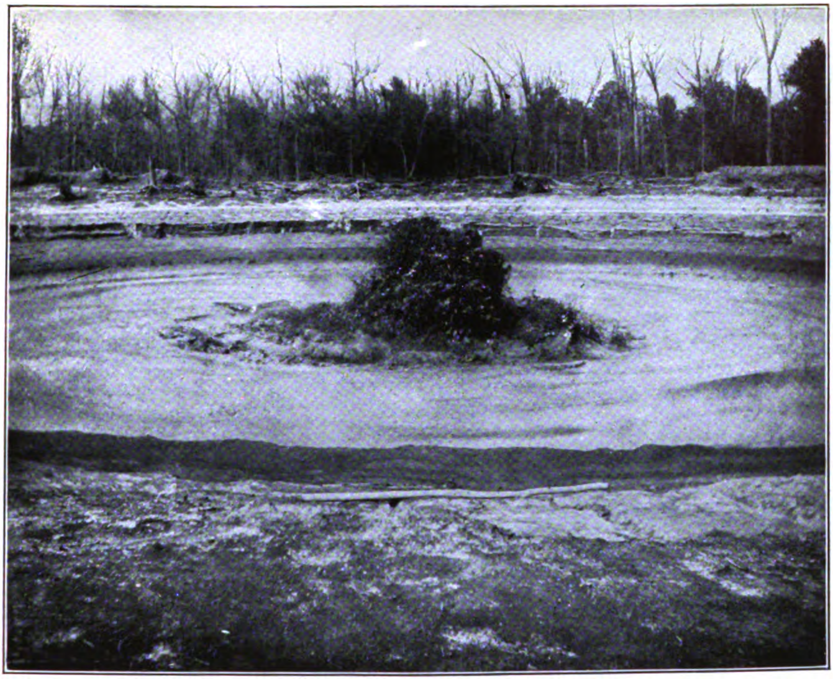
ANALYSIS OF GAS FROM THE CADDO FIELD.

The analysis and remarks of Prof. F. C. Phillips, frequently quoted in technical journals, may be repeated here:

Analysis of gas from Caddo field.

Methane	95.00
Nitrogen	2.56
Carbon dioxide	2.34
Hydrogen	.00
Carbon monoxide	.00
Ethylene	.00
Sulphide (sulphide hydrogen?)	.01

I think you have a valuable fuel in this gas, well suited for household heating or for metallurgical purposes, and for all purposes to which natural gas is applied.



A. CADDO GAS AND OIL COMPANY'S WELL ON GILBERT TRACT, 1¼ MILES SOUTH OF OIL CITY, DECEMBER, 1908.

The "crater," 300 feet across, was excavated by wave action. Red, thick, muddy water is here being tossed 30 feet in the air by the force of the escaping gas. When ignited the flames are from 40 to 70 feet in height.

B. DAWES TRUSTEE WELL NO. 1, CADDO FIELD.

Burning gas well with flame 125 feet high. The small white object at the left is the outline of a man. Photograph taken at night, December, 1908.

WELLS IN THE CADDO FIELD.

The following annotated list of the wells in the Caddo field, arranged alphabetically, has been compiled by I. Perrine. Corrections and additions to the data here given will be gladly received. The information is complete as far as possible to February 15, 1909. Dates are derived mainly from the Oil Investors' Journal:

Arnell & Lee No. 1. See Lee & Arnell No. 1.

Augur & Henderson well, near Shreveport. See Henderson & Augur well.

Alday & Daniel No. 1. See Daniel & Alday No. 1.

Barnhart No. 1, McGuire; NW. ¼ NW. ¼ NW. ¼ sec. 21, T. 20 N., R. 15 W. Began drilling April, 1907. A 15,000,000-foot gasser at 812 feet June 5, 1907. Well capped.

Barnhart No. 2, McGuire; NE. ¼ NE. ¼ NW. ¼ sec. 21, T. 20 N., R. 15 W. Began drilling June, 1907. A 15,000,000-foot gasser at 795 feet June 5, 1907. Well capped.

Belcher. A well was to be drilled here, 17 miles north of Shreveport, February 3, 1907.

Benedum & Trees No. 1; on the J. Stiles place. Derrick up October 6, 1908; drilling October 20–November 20, 1908.

Big Four No. 1; NW. ¼ SE. ¼ sec. 1, T. 20 N., R. 16 W. Rig up February 3, 1907. Down 1,560 feet June 5, 1907. Produced 500–600 barrels of oil which has to be treated. Also called McCormick No. 1 on the Guy 5 acres. Well was being cleaned August 6, 1908.

Big Four No. 2; S. ½ NW. ¼ SE. ¼ sec. 1, T. 20 N., R. 16 W. Drilled to 2,240 feet by Del Southerland. Had a good showing of oil at 1,580 feet. A good producer. Well being cleaned January 10, 1909.

Black Bayou No. 1, Alexander; SE. ¼ SE. ¼ sec. 9, T. 20 N., R. 15 W. Derrick up October 20, 1908. Drilling November 6, 1908, to January 20, 1909. A 125-barrel well.

Black Bayou No. 1, Glassell; SW. ¼ sec. 10, T. 20 N., R. 15 W. Drilling June 10 to October 6, 1908. A 300-barrel well.

Blanchard No. 1, Surrey; NW. ¼ NW. ¼ SE. ¼ sec. 12, T. 20 N., R. 16 W. Formerly called Offenhauser No. 4. Drilling October 8, 1907, to February, 1908.

Blanchard No. 2, Surrey; NE. ¼ NW. ¼ SE. ¼ sec. 12, T. 20 N., R. 16 W. Completed July 6, 1908. A 100-barrel well.

Blanchard No. 3, Surrey; S. ½ SW. ¼ SE. ¼ sec. 12, T. 20 N., R. 16 W. Derrick up September 30, 1908. Drilling October 6, 1908, to February 15, 1909. The well was shut down through November and part of December, 1908, and January, 1909.

Blanchard No. 4, Surrey; NE. ¼ NE. ¼ SW. ¼ sec. 12, T. 20 N., R. 16 W. A derrick only.

Blanchard No. 1, Graham; sec. 35, T. 20 N., R. 16 W. Completed July 6, 1908. A dry hole at 2,504 feet.

Bossier City, Shreveport well. A water well owned by the Shreveport Cottonwood Company; struck gas at 500 feet and will drill deeper in search of oil.

Broussard No. 1, Brown; NE. ¼ NE. ¼ SW. ¼ SW. ¼ sec. 18, T. 20 N., R. 15 W. Drilling January 1 to February 15, 1909. Also called B. G. Dawes and others No. 1, Brown.

Broussard No. 1, fee; SE. ¼ SW. ¼ SW. ¼ SW. ¼ sec. 6, T. 20 N., R. 15 W. Owner, B. G. Dawes. Congressman Oil Company. Drilling June 1 to August 1, 1908. A 100-barrel producer. McCann & Harper, contractors.

Broussard No. 2, fee; SE. ¼ SE. ¼ SW. ¼ SW. ¼ sec. 6, T. 20 N., R. 15 W. Drilled in Clear Lake bottoms. A 100-barrel producer. Harper, driller.

Brown No. 1; S. ½ NE. ¼ NW. ¼ SW. ¼ sec. 1; T. 20 N., R. 16 W. Twisted off at 1,440 feet; hole still remains; 50 feet north of Hunter No. 1.

Brown Brothers No. 1; NW. ¼ SW. ¼ SE. ¼ sec. 1, T. 20 N., R. 16 W. Heavy oil at 900–1,000 feet; at 1,300 feet the same oil was found as in the old Moricell-Savage well, July 3, 1905. Completed at 1,560 feet, a 3 to 4 barrel well, November 3, 1905. Afterward made a 4,000,000-foot gasser, January 3, 1906. Owner, S. A. Nunnelley. Gas still being used February 10, 1909.

Busch-Everett No. 1, Douglas; SW. ¼ sec. 30, T. 20 N., R. 14 W. Dixie, La. Drilling January 20 to February 15, 1909.

Byron No. 1, McGuire; NE. ¼ SE. ¼ sec. 17, T. 20 N., R. 15 W. Equals old McGuire No. 1, his first well. A 20,000,000-foot gasser at 802 feet.

Caddo Gas and Oil Company. Black Diamond No. 1, Black Diamond, Arkansas. Drilling June to October 1, 1907. A dry hole at 1,800 feet. C. E. Latham, driller.

Caddo Gas and Oil Company. Caddo Lake Oil and Pipe Line Company No. 1; SW. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. Quoted as C. G. O., Smith No. 6, in Oil Investors' Journal. Derrick up April 19, 1908. Drilling July 20 to December 20, 1908. A 2,500-barrel well from the 1,580-foot stratum; gravity 30° Baumé. The best well in the field.

Caddo Gas and Oil Company. Caddo Lake Oil and Pipe Line No. 2; SW. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. Drilling December 17, 1908, to February 15, 1909.

Caddo Gas and Oil Company. Caddo Lake Oil and Pipe Line No. 3; SW. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. Derrick up December 20, 1908.

Caddo Gas and Oil Company. Mary L. Cook No. 1; SW. ¼ sec. 32, T. 20 N., R. 15 W. Began drilling February 6, 1909.

Caddo Gas and Oil Company. Croom Club House No. 1; SE. ¼ NE. ¼ NW. ¼ NE. ¼ sec. 35, T. 19 N., R. 16 W. Drilling January 3 to January 15, 1907. A gas well at 820 feet. C. E. Latham, driller. Is at present being deepened.

Caddo Gas and Oil Company. No. 1; Dixie. Drilling January 6 to February 15, 1909.

Caddo Gas and Oil Company. Donnell No. 1, state line well, Texas, La., due west of Vivian. Derrick up June 6, 1908. Drilling July 20 to October 6, 1908. Shut down at 1,175 feet, waiting for further orders. C. E. Latham, driller.

Caddo Gas and Oil Company. Draper No. 1, Draper, Tex. Drilling March 7 to June, 1907. A dry hole.

Caddo Gas and Oil Company. Fee simple; sec. 1, T. 20 N., R. 16 W. Rig up May 5, 1908. A 200-barrel well, May, 1908.

Caddo Gas and Oil Company. Gilbert No. 1 (oil); NW. ¼ NE. ¼ NE. ¼ sec. 13, T. 20 N., R. 16 W. Drilling July 20 to September 6, 1908. A 400-barrel well. Gravity oil 43° Baumé.

Caddo Gas and Oil Company. Gilbert No. 2 (oil); NE. ¼ NE. ¼ NE. ¼ sec. 13, T. 20 N., R. 16 W. Drilling September 20 to November 6, 1908. A 90-barrel producer.

Caddo Gas and Oil Company. Gilbert No. 1 (gas); NE. ¼ NE. ¼ SE. ¼ sec. 13, T. 20 N., R. 16 W. Formerly called Citizen's Oil and Pipe Line Company No. 1 on the Gilbert tract, just north of Caddo Lake. A great blow-out; dynamited November 4, 1906, to no advantage. This well is known as the burning mud and oil geyser.

Caddo Gas and Oil Company. Gilbert No. 2 (gas); NW. ¼ NW. ¼ NE. ¼ sec. 13, T. 20 N., R. 16 W. Drilling October to November 18, 1905. A good gasser. This well was on the line to Shreveport in February, 1906, but is not used at present.

Caddo Gas and Oil Company. Gilbert No. 3; SE. ¼ NE. ¼ SE. ¼ sec. 13, T. 20 N., R. 16 W. A good gasser, 1906, over which a new derrick has recently been built.

Caddo Gas and Oil Company. Gilbert No. 4; SE. ¼ SE. ¼ SE. ¼ sec. 13, T. 20 N., R. 16 W. Drilling October 12 to November, 1906; a good gasser at 775 feet. C. E. Latham, driller.

Caddo Gas and Oil Company. Gilbert No. 5; NE. ¼ NE. ¼ NE. ¼ sec. 13, T. 20 N., R. 16 W. Also called the Henning well. A gas well.

Caddo Gas and Oil Company. Glassell No. 1; SW. ¼ SE. ¼ sec. 10, T. 20 N., R. 15 W. Drilling January 6 to February 15, 1909.

Caddo Gas and Oil Company. Harris No. 1; NW. ¼ SW. ¼ SW. ¼ sec. 29, T. 19 N., R. 15 W. Derrick up December 1, 1908. Completed December 17, 1908. A dry gasser, from the 800-foot stratum.

Caddo Gas and Oil Company. Hiner No. 1, Vivian, La.; NW. ¼ SE. ¼ SE. ¼ sec. 26, T. 22 N., R. 16 W. Drilling July 20 to September 10, 1908. A dry hole. C. E. Latham and J. E. Todd, drillers.

Caddo Gas and Oil Company. Hostetter No. 1. Drilling January 7 to January 19, 1907. A 15,000,000-foot gasser at 783 feet. W. H. Harper, driller. This well was turned into the gas line to Shreveport for a five-day test. It supplied Shreveport through 22 miles of 6-inch line and held a line pressure of 245 pounds at the Shreveport regulator station.

Caddo Gas and Oil Company. Hostetter No. 3. Drilling December 31, 1907, to January 4, 1908. A 7,000,000-foot gasser at 780 feet. On a three-minute test it held a rock pressure of 300 pounds. The gas is dry and clean. Is at present on the Shreveport line.

Caddo Gas and Oil Company. Hostetter No. 4. Drilling January 21 to February 11, 1908. A good gasser, at present on the Shreveport line. Depth 778 feet. This well was bailed at a depth of 777 feet and developed a volume capacity of 6,000,000 cubic feet a day and a rock pressure of 265 pounds on a two-minute test. The gas was dry and clean. The well when shut in developed a peculiar phenomenon, the gas working back of the 8-inch pipe and coming up to the bottom of the 10-inch pipe only 83 feet 9 inches from the surface; but the 10-inch pipe was successfully cemented and in this way the escape of the gas was cut off. However, within twelve hours from the time the well had been shut in, the gas worked through crevices in the rock shell on which the 10-inch pipe had been set and came up in a channel of Caddo Lake, extending out as far as half a mile from the well. The surface of the lake had the appearance of a violent storm, the escaping gas blowing the water as high as 20 feet in places, but as soon as the well was opened the gas came back through the 8-inch pipe and the escape by way of the lake ceased. The well was at once lubricated and killed by pumping it full of mud. The 8-inch pipe was pulled, a well packer was set 65 feet from the bottom, the casing was reduced to 6 inches, and a string of 8-inch pipe was washed over the 6-inch pipe to the well packer. As the 8-inch pipe was withdrawn, the well was filled in back of the 6-inch pipe with concrete to the top of the ground. After allowing this to set for three days the well was again bailed in and allowed to blow open for seven days to let the concrete set thoroughly. The well when shut in was in good shape, and no further escape of gas occurred. After standing for a few days it was connected with the line to Shreveport and on January 1, 1909, was supplying that city with gas. J. M. Guffey Petroleum Company and S. S. Hunter, owners; W. H. Harper, contractor; J. B. McCann, agent.

Caddo Gas and Oil Company, Hunter No. 1; E. ½ NW. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. The first shallow well, about 1,580 feet deep. A 300-barrel well.

Caddo Gas and Oil Company, Hunter No. 2; S. ½ NW. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. Drilling November 20, 1908, to January 20, 1909. A 65-barrel well.

Caddo Gas and Oil Company, Leary No. 1, Leary, Tex., on the Midden farm. Drilling October 22, 1907, to March 7, 1908. A dry hole at 1,800 feet.

Caddo Gas and Oil Company, McDowell No. 1. Completed June 20, 1908. A dry hole; may drill deeper. This well was abandoned after a blowout, June 20, 1908.

Caddo Gas and Oil Company, McDowell No. 2. Completed August 20, 1908. A dry hole. May drill deeper.

Caddo Gas and Oil Company, Noel No. 1; NE. ¼ NW. ¼ SE. ¼ NW. ¼ sec. 1, T. 19 N., R. 16 W. A gas well, capped.

Caddo Gas and Oil Company, Noel No. 2; S. ½ NW. ¼ NW. ¼ sec. 1, T. 19 N., R. 16 W. Completed at 2,460 feet. A dry hole.

Caddo Gas and Oil Company, Noel No. 3; NW. ¼ NW. ¼ SE. ¼ NW. ¼ sec. 1, T. 19 N., R. 16 W. Completed December, 1906. A gas well at 860 feet.

Caddo Gas and Oil Company, Offenhauser No. 1; NE. ¼ SE. ¼ sec. 1, T. 20 N., R. 16 W. Formerly called Caddo Oil and Mining Company, Hunter & Hughes No. 1. Completed June 5, 1907. A 150-barrel well with some gas at 2,170 feet. A small derrick was used in drilling this well. The well is now producing.

Caddo Gas and Oil Company, Offenhauser No. 2; NE. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. Formerly called Citizens' Oil and Pipe Line Company No. 2, or the Hughes-Offenhauser well. Completed May 1, 1908. A 250-barrel well.

Caddo Gas and Oil Company, Offenhauser No. 3; SE. ¼ NE. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. Formerly called Thompson No. 1. Rig up May 5, 1908. Drilling May 19 to October 20, 1908. A 75-barrel well.

Caddo Gas and Oil Company, Offenhauser No. 4; NW. ¼ NE. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. Formerly called Thompson No. 2. Drilling July, 1908. At present a small producer.

Caddo Gas and Oil Company, Pardue No. 1, Vivian, La.; SW. ¼ NW. ¼ sec. 1, T. 21 N., R. 16 W. Completed December 6, 1908. A 2,500,000-foot gasser.

Caddo Gas and Oil Company, Smith No. 1; SE. ¼ SW. ¼ sec.1, T. 20 N., R. 16 W. Formerly called the McCormick gas well. A gasser from the 800-foot stratum.

Caddo Gas and Oil Company, Smith No. 2; NE. ¼ SE. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. Formerly called the Baby well. At 1,050 feet the well was bailed January, 1905, and developed salt water, flowing 80 feet above the derrick. After 203 days' flow it developed pure gas and is at present a small gasser.

Caddo Gas and Oil Company, Smith No. 3; N. ½ SE. ¼ sec. 1, T. 20 N., R. 16 W. Drilling June 7 to October 2, 1907. After the strainer was set a big salt-water well with gas and oil developed. On trying to pull the strainer it became choked and blew out. The well flowed for several days, a 15-barrel well with much salt water, but drowned out in ten days. In setting the 4-inch pipe it parted at a collar when 100 feet from the bottom because of a defective joint under the elevator, completely plugging the hole. All the pipe but 150 feet was fished out and the hole was abandoned, June 1, 1908.

Caddo Gas and Oil Company, Smith No. 4; SW. ¼ SE. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. Drilling November 28, 1907, to February 28, 1908. When the well was bailed in it developed from the deep sand a yield of 500 barrels. The oil was dark green in color and of 28.4° Baumé gravity at 60° F. This well was the best in the field when completed. It was cleaned out September 6, 1908, and is still a good producer.

Caddo Gas and Oil Company, Smith No. 5; SW. ¼ SE. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. Drilling March 7 to May 20, 1908, at 2,280 feet. Salt water drowned the well; 17 feet of cement was put in the bottom without effect. The well is not now producing.

Caddo Gas and Oil Company, Smith No. 6; NW. ¼ NE. ¼ SE. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. A derrick only.

Caddo Lake Oil and Pipe Line No. 1. Formerly called Savage Brothers and Morricell. This is the oldest well in the field. Rig up May, 1904; drilling began in June, 1904. A partial log is as follows: Lignite at 16 feet; rock, gravel, and bowlders to 300 feet; a good fresh-water well at 85 feet; gas sand at 900 feet; 6-inch pipe set at 1,400 feet; drilling stopped at 1,556 feet in cream-colored shale with pyrite April 3, 1905. The well was bailed March 28, 1905. A 5-barrel well; deepened in July, 1905; idle November, 1905; gasser January 3, 1906; oozed oil of 34.7° Baumé gravity August, 1906, but not in paying quantities. Abandoned June, 1907.

Caddo Lake Oil and Pipe Line Company No. 2. A new well started south of No. 1 May 18, 1905. A heavy oil was found at 950 feet; down 1,035 feet in shale, January 3, 1906.

Caddo Lake Oil and Refining Company. In this well rock was struck at 1,400 feet; oil at 1,546 feet, of 35° Baumé. The oil came within 700 feet of the surface February 3, 1905.

Caddo Oil and Mining Company. Rig up September 19, 1907.

Citizens' Oil and Pipe Line Company; S. ½ SE. ¼ sec. 8, T. 19 N., R. 16 W. Also called Jeter well.

Cooper & Heard No. 1, Cooper, Winnfield, La. Drilling December 20, 1908, to February 15, 1909.

Crawford No. 1, McGuire; SW. ¼ SW. ¼ NE. ¼ SW. ¼ sec. 17, T. 20 N., R. 15 W. A 15,000,000-foot gas well.

Culliman & Jolly No. 1; NW. ¼ SE. ¼ SW. ¼ sec. 18, T. 20 N., R. 15 W. Completed December 18, 1906. A 15,000,000-foot gasser at 110 feet; now owned by the Louisiana Oil Company.

Daniel & Alday No. 1; SW. ¼ SE. ¼ NW. ¼ sec. 31, T. 21 N., R. 15 W. (?). Blew out gas and salt water and is not now a producer.

C. G. Dawes Trustee No. 1; SE. ¼ NE. ¼ SW. ¼ sec. 7, T. 20 N., R. 15 W. Began drilling March 17, 1908, but was lost before being finished. On the night of May 11, 1908, during a heavy rain storm, while the 4-inch rotary pipe was being put back and was about 350 feet from the bottom, the well blew out from the gas stratum between 1,360 and 1,420 feet, making 40,000,000 cubic feet of gas a day under very high pressure and showing a small amount of salt water. While preparations were being made to lubricate and kill the well the derrick was completely destroyed by a cyclone on the evening of May 13. Deeper gas worked through the 8¼-inch casing in a defective seam or joint or under the bottom and started the 800-foot or Caddo gas stratum to blowing out. This in turn worked through a split in the 10-inch pipe 20 feet below the surface and blew out a very large hole about 20 feet deep around the top of the 10-inch pipe. After several days the drillers succeeded in getting a joint of 14-inch pipe over the 10-inch and in concreting a shoulder on the bottom of the 14-inch to the 10-inch. Then they built a concrete anchor to the 14-inch pipe, hoping in this way to be able to hold the gas long enough to lubricate and kill the well by pumping it full of mud. But the gas caught fire and burned from June, 1908, till the night of February 12, 1909. The gas was lighted the next morning, but went out again within five minutes. Some salt water appeared and with the gas forms a spray that still rises above the old hole. This well is the one which has been noted as the "burning gas well."

C. G. Dawes Trustee No. 2; SE. ¼ SE. ¼ NE. ¼ SW. ¼ sec. 7, T. 20 N., R. 15 W. Drilling June 22 to August, 1908. A 10 to 15 barrel well with much salt water. Not producing at present.

B. G. Dawes and Caddo Gas and Oil Company No. 1, Christian; Vivian, La. A location only.

B. G. Dawes and Gulf Refining Company, Heilperin No. 1; NW. ¼ SE. ¼ NW. ¼ sec. 31, T. 22 N., R. 15 W. Drilling September 29 to October 22, 1908. A 15,000,000-foot gasser. S. B. Clement, driller.

B. G. Dawes and Gulf Refining Company, Posey No. 1; SE. ¼ NE. ¼ NW. ¼ sec. 25 T. 22 N., R. 16 W. Drilling September 15 to October 28, 1908. A dry hole.

Dawes No. 1, J. W. White. Rig up July 20, 1908. Taken down since.

Dixie Oil and Pipe Line Company No. 1. A 2,250-foot well. Abandoned September 19, 1907.

Dixie No. 2, Glassell; SE. ¼ sec. 36, T. 20 N., R. 15 W., 5½ miles east of Mooringsport. A gasser September 19, 1907.

Dixon Oil and Pipe Line Company; sec. 22, T. 20 N., R. 15 W., 4 miles east of Mooringsport. Gumbo at 875 feet; shale and sand at 2,025 feet.

Dixon Oil and Pipe Line Company No. 1; NW. ¼ SW. ¼ NW. ¼ sec. 33, T. 21 N., R. 15 W., on Pine Island, one-half mile east of Texla No. 1. A blowout occurred at

2,165 feet; the well was killed and deepened to 2,500 feet. Casing pulled June 19, 1907.

Dixon Oil and Pipe Line Company No. 2; NW. ¼ NW. ¼ SW. ¼ sec. 33, T. 21 N., R. 15 W. Completed as a gasser at 840 fee . About 1,500,000 feet capacity March 19, 1907.

Enterprise No. 1, Noel; sec. 12, T. 20 N., R. 16 W. Completed June 19, 1908. A fairly good producer.

Enterprise No. 2, Noel; sec. 12, T. 20 N., R. 16 W. Completed September 6, 1908. A 10-barrel well; 70 barrels gross.

Enterprise No. 3, Noel; NE. ¼ SW. ¼ NW. ¼ SE. ¼ sec. 12, T. 20 N., R. 16 W. A derrick only.

Evans No. 1, McGuire; SE. ¼ NE. ¼ SE. ¼ SW. ¼ sec. 18, T. 20 N., R. 16 W. A 15,000,000-foot gasser at 812 feet June 5, 1907.

Evans No. 2, McGuire; E. ½ NE. ¼ SE. ¼ SW. ¼ sec. 18, T. 20 N., R. 15 W. A 15,000,000-foot gasser, 2,000 feet north of Evans No. 1, June 5, 1907.

Evans No. 3, McGuire; NE. ¼ NW. ¼ NE. ¼ SE. ¼ sec. 18, T. 20 N., R. 15 W. A good gasser, June 5, 1907.

Filer No. 1; NE. ¼ NW. ¼ NW. ¼ SE. ¼ sec. 7, T. 20 N., R. 15 W. Completed July 28, 1908. A 140-barrel well; now producing very little.

Filer No. 2; just southeast of the center of sec. 7, T. 20 N., R. 15 W. Derrick up July 20, 1908. Well completed November 6, 1908. A 30-barrel well.

Filer No. 3, or 1–18; S. ½ NW. ¼ NW. ¼ NE. ¼ sec. 18, T. 20 N., R. 15 W. Completed February 6, 1909. A 100-barrel well.

Guffey No. 1, Christian; sec. 31, T. 20 N., R. 15 W. Derrick up May 5, 1908, but was blown over by a high wind and site was abandoned.

Guffey Hostetter No. 1; SE. ¼ sec. 30, T. 20 N., R. 15 W. Began drilling January 22, 1907. On March 19, 1907, the well blew out at 2,208 feet, with 613 feet of 8-inch casing in the hole. When a depth of 2,209 feet was reached the well was shut down and preparations were made to set the 6-inch pipe, but as soon as the pump pressure was shut off the well blew out and, having at the time only 613 feet of 8-inch casing in the hole, was completely destroyed by the terrific gas pressure, developing a rock pressure of nearly 1,000 pounds. After blowing out for three days, the deep gas stratum was choked off by the collapse of the cofferdam placed around the 8-inch pipe to a depth of 29 feet on top of the first rock stratum, after a string of 12-inch pipe had been driven around the 8-inch. The well was then concreted to the top of the ground and in this way was shut in finally and the blowout stopped. This well, when the gate was opened during the fall of 1908, began to flow, and averaged from 10 to 30 barrels of high-grade oil a day for several months, but finally stopped flowing when a well was brought in near by.

Guffey Hostetter No. 2. Drilling June to December 8, 1908. A 300-barrel well. This well was claimed to be making 10,000 barrels when first completed and caused a great stir in the field, but later reports show that its average capacity is nearer 200 barrels.

Guffey Pitt No. 1; NW. ¼ NW. ¼ NW. ¼ sec. 7, T. 20 N., R. 15 W. Derrick up July 3, 1905. Now abandoned.

Guffey No. 1, Dixon farm; NW. ¼ sec. 33, T. 20 N., R. 15 W. On Pine Island. Down 2,200 feet June 5, 1907.

Gulf-Broussard No. 1, Pitts; sec. 20, T. 20 N., R. 15 W. Began drilling February 6, 1909.

Gulf Refining Company No. 1, Christian; NE. ¼ SW. ¼ SW. ¼ sec. 30, T. 20 N., R. 15 W. Rig up February 6, 1909.

Gulf Refining Company No. 1, Curtis; N. ½ NE. ¼ SE. ¼ sec. 19, T. 20 N., R. 15 W. Derrick up January 1, 1909. Began drilling February 6, 1909.

Gulf Refining Company No. 1, Edwards; NE. ¼ sec. 31, T. 20 N., R. 15 W. Drilling February 6, 1909.

Gulf Refining Company No. 1, J. Harris; sec. 32, T. 19 N., R. 15 W. Began drilling January 6, 1909.

Gulf Refining Company No. 3, Hostetter. Began drilling February 6, 1909.

Gulf Refining Company No. 1, Mason. Began drilling February 6, 1909.

Gulf Refining Company No. 2, Mason. Derrick up January 6, 1909.

Gulf Refining Company No. 1, Nunnelley. Derrick up December, 1908. Began drilling January, 1909.

Gulf Refining Company No. 1; SW. ¼ sec. 30, T. 20 N., R. 15 W. Drilling January, 1909.

Hastings Oil Company. Rig up June 18, 1905.

Henderson & Augur, well near Shreveport, on Douglas Island. Abandoned at 2,250 feet December 3, 1905. This well produces some salt water and gas. Shoots up 10 feet in the air, and the gas when lighted will burn for a short time, but soon goes out.

Heywood No. 1, Fee; NW. ¼ NW. ¼ SW. ¼ SE. ¼ sec. 1, T. 20 N., R. 16 W. Drilling September to December, 1908. A dry hole at 2,257 feet. H. Jones, driller.

Heywood No. 1, Savage; SE. ¼ SE. ¼ NE. ¼ SE ¼ sec. 2, T. 20 N., R. 16 W. Drilling December, 1908, to February, 1909. A dry hole, with show of oil in the 1,500-foot stratum.

Hope No. 1, Hope, Ark. Drilled by A. P. Dyke on the Dyke tract. The 8-inch pipe was down 240 feet December 18, 1908.

Huckaby No. 1, McGuire; SE. ¼ SW. ¼ SW. ¼ sec. 17, T. 20 N., R. 15 W. A 25,000,000-foot gasser at 823 feet, June 5, 1907.

Jolly No. 1. See Culliman & Jolly No. 1.

Jolly No. 2, NW. ¼ NE. ¼ SW. ¼ SW. ¼ sec. 17, T. 20 N., R. 15 W. A gas well drilled in 1907. Now owned by Louisiana Gas Company.

Latex Oil and Pipe Line Company No. 1; SW. ¼ SW. ¼ SW. ¼ sec. 3, T. 20 N., R. 16 W. Twisted off at 1,800 feet, but found traces of oil July 18, 1905.

Latex Oil and Pipe Line Company No. 2, S. ½ SW. ¼ SW. ¼ sec. 3, T. 20 N., R. 16 W. The third well drilled in the field. Not producing now.

Lee & Arnett No. 1; sec. 10, T. 18 N., R. 14 W. Began drilling December, 1905. Struck gas stratum at 975 feet June 3, 1906. This well is 3 miles northwest of Shreveport and is not producing now.

Lee & Arnett No. 2; 900 feet west of No. 1; struck gas at about the same depth. Not producing now.

J. A. Libby. Had a derrick up on the S. A. Guy 30-acre tract June 18, 1905.

Lillie No. 1; N. ½ NW. ¼ NW. ¼ sec. 12, T. 20 N., R. 16 W. Completed June, 1908. A 100-barrel well. A fairly good producer.

Lillie No. 2; NW. ¼ NW. ¼ NW. ¼ sec. 12, T. 20 N., R. 16 W. Derrick up December, 1908. About January 1, 1909, the hole was lost at 1,440 feet.

Lillie No. 2, second hole; about 10 feet north of the old Lillie No. 2. Drilling February 6, 1909.

Lillie No. 3. Drilling February 1, 1909.

Mansfield No. 1; NE. ¼ SE. ¼ SE. ¼ SE. ¼ sec. 1, T. 20 N., R. 16 W. Drilling December, 1908, to February, 1909. A 125-barrel well.

Marshall Gas Company No. 1, R. T. Cole, Blanchard, La. Rig up November 6, 1908. Drilling November, 1908, to February 15, 1909. This well and a half interest in the holdings of King Brothers, the owners, were bought by Producers' Oil Company, which will drill to 1,500 feet or more. The well was down 1,100 feet in February, 1909.

Marshall Gas Company No. 1, near Blanchard. Derrick up September, 1908. Never drilled.

Marshall well; on Blocker place, 10 miles southeast of Marshall, Tex. This well was down 1,500 feet January, 1909, and was still drilling February 15.

Marshall & Hardy No. 1. See Texla No. 1.

McCann & Harper No. 1, Pitts; NE. ¼ NW. ¼ sec. 31, T. 22 N., R. 15 W. Drilling February, 1909.

McCormick No. 1, Croom. Derrick up September 14, 1908. Well completed February, 1909. A 50-barrel well. Driller, Sel Southerland.

McCormick No. 1, Mooringsport. All traces of this derrick have been removed. The derrick was blown over by a strong wind and the site was abandoned.

McCormick No. 2, Mooringsport. Also called Thompson No. 1. This derrick also was destroyed by the strong wind and the site was abandoned.

McCormick No. 1, Shreveport. Also called the Brickyard well. This well was drilled in the winter of 1904 and 1905 and is the second oldest well in the field. It was drilled to 1,650 feet in search of gas as fuel for burning brick. At 910 feet there was a show of gas, but salt water spoiled all chances of obtaining a good well at this depth. The well was later drilled to a depth of 2,000 feet, but no oil was obtained.

McGuire wells. See under the names of the individual wells.

Merchant No. 1; NE. ¼ NE. ¼ SW. ¼ SW. ¼ sec. 6, T. 20 N., R. 15 W. Derrick up December 25, 1908. Drilling February, 1909.

Nichols Oil and Gas Company No. 1; north of Paraloma, Ark. Began drilling August, 1908; down 535 feet December 14, 1908. Driller, R. H. Ferguson, Milford, Ark.

Producers No. 1, Black Bayou; SE. ¼ NE. ¼ SE. ¼ SE. ¼ sec. 7, T. 20 N., R. 15 W. Derrick up July 19, 1907. Well completed November, 1907. A 100-barrel producer, but the oil has to be cooked. This well had an initial capacity of 700 barrels.

Producers No. 2, Black Bayou; W. ½ SE. ¼ SE. ¼ sec. 7, T. 20 N., R. 15 W. Drilling April to August, 1908. A 50-barrel well with considerable gas.

Producers No. 3, Black Bayou; W. ½ SW. ¼ NE. ¼ sec. 18, T. 20 N., R. 15 W. Derrick up October, 1908. Well completed December 7, 1908. A 90-barrel producer. The gravity of the oil in this well is 37.3° Baumé.

Producers No. 1; NW. ¼ SW. ¼ SE. ¼ sec. 1, T. 20 N., R. 16 W. This well was a good gasser at 812 feet, but blew out and is now a large salt-water blower.

Producers No. 2, Caddo Oil and Mining Company. Gas was struck in this well at 750 to 850 feet. The well was completed at 830 feet, but a blow-out occurred which blew sand and mud all over the derrick, April 13, 1905.

Producers No. 3, Caddo Oil and Mining Company. Drilling June to July, 1905. A blow-out occurred in this well also and the well was lost.

Producers No. 4, Caddo Oil and Mining Company. This well was put down to kill the two blow-outs, Nos. 3 and 4, on the Caddo Oil and Mining lease. The well was completed March 9, 1906. A small gasser at 842 feet. When this well was brought in the two geysers ceased to be active, and their sites are now marked by salt lakes.

Producers No. 5, Caddo Oil and Mining Company; SW. ¼ NE. ¼ sec. 12, T. 20 N., R. 16 W. This well is 2,000 feet south of No. 2. Rock was struck at 185 feet; sand and shale at 1,650 feet, and at 2,180 feet a strong gas pressure developed. The well was completed as a 190-barrel producer August 5, 1907.

Producers No. 6, Caddo Oil and Mining Company. Drilling November 5, 1907, to June 19, 1908. A 50-barrel well.

Producers No. 7, Caddo Oil and Mining Company. Drilling April to June 19, 1908. A 100-barrel well.

Producers No. 8, Caddo Oil and Mining Company. A derrick only.

Producers No. 1, Evans; SE. ¼ SE. ¼ NE. ¼ sec. 11, T. 20 N., R. 16 W. Completed April, 1908. A 35-barrel well, which has since turned mostly to gas.

Producers No. 1, Fee; NE. ¼ sec. 30, T. 20 N., R. 15 W. Mooringsport. Began drilling January 20, 1909.

Producers No. 1, Harrell; SE. ¼ NE. ¼ SE. ¼ sec. 30, T. 21 N., R. 15 W., on Pine Island, 1 mile northwest of Texla No. 1, on the Harrell 204-acre tract. Drilling November, 1906, to June, 1907. A dry hole at 3,000 feet; since abandoned. This well is the deepest in the field.

Producers No. 2, Harrell; NE. ¼ SE. ¼ sec. 2, T. 21 N., R. 16 W. Began drilling July 1908, and was still drilling in February, 1909.

Producers No. 1, Heilperin & Liebman; SW. ¼ NE. ¼ SW. ¼ sec. 31, T. 21 N., R. 15 W., on Pine Island. A 75-barrel well at 1,400 feet (?). Deepened and producing 20 barrels February, 1908.

Producers No. 2, Heilperin & Liebman; NE. ¼ SW. ¼ NE. ¼ SW. ¼ sec. 31, T. 21 N., R. 15 W., on Pine Island, 500 feet north of No. 1; reported as a producer at 1,400 feet. A blowout occurred at 2,154 feet. The well turned to a gasser in June, 1908.

Producers No. 1, J. W. Holt; SE. ¼ NE. ¼ SE. ¼ SE. ¼ sec. 2, T. 20 N., R. 16 W. Drilling December, 1908, to February, 1909. A dry hole.

Producers No. 1, Homestead; sec. 12, T. 20 N., R. 16 W. Drilling February to May, 1908. A 100-barrel well.

Producers No. 2, Homestead; S. ½ SW. ¼ SE. ¼ SE. ¼ sec. 12, T. 20 N., R. 16 W. Began drilling September, 1908. Twisted off and abandoned.

Producers No. 3, Homestead; SW. ¼ SE. ¼ SE. ¼ sec. 12, T. 20 N., R. 16 W. Began drilling November, 1908, with the rig formerly used in drilling No. 2. Completed January 6, 1909. A 70-barrel well.

Producers No. 1, Lane. Drilling June to September, 1908. A 400-barrel well.

Producers No. 2, Lane; NW. ¼ NE. ¼ NW. ¼ sec. 18, T. 20 N., R. 15 W. Drilling June to October, 1908. A 300-barrel well. This well has been often reported to be making from 2,000 to 3,000 barrels and probably is good for 500 barrels.

Producers No. 3, Lane; SW. ¼ SE. ¼ NE. ¼ NW. ¼ sec. 18, T. 20 N., R. 15 W. Began drilling December, 1908.

Producers No. 4, Lane; SW. ¼ SW. ¼ NE. ¼ NW. ¼ sec. 18, T. 20 N., R. 15 W. Began drilling December, 1908.

Producers No. 1, Leonard; NW. ¼ NE. ¼ NW. ¼ NW. ¼ sec. 6, T. 20 N., R. 15 W., on Pine Island. Began drilling February, 1907. A 9,000,000-foot gasser at 2,128 feet, April, 1907.

Producers No. 1, J. Milam; SW. ¼ sec. 6, T. 19 N., R. 15 W. Began drilling February, 1909.

Producers No. 1, Murray; NW. ¼ NE. ¼ SE. ¼ sec. 12, T. 20 N., R. 16 W. Drilling October, 1907, to January, 1908. A 100-barrel well.

Producers No. 2, Murray; NE. ¼ NE. ¼ NE. ¼ SE. ¼ sec. 12, T. 20 N., R. 16 W. Drilling July, 1908, to February 6, 1909; a gasser.

Producers No. 1, Murray, Colquitt & Hardy; NW. ¼ NW. ¼ sec. 18, T. 20 N., R. 15 W. Drilling September to December, 1908. A 125-barrel well.

Producers No. 1, Richardson; NE. ¼ NW. ¼ NW. ¼ sec. 12, T. 20 N., R. 16 W. Drilling May to August, 20, 1908. A 50-barrel well.

Producers No. 1, Ruddersdorf; NE. ¼ NE. ¼ NW. ¼ sec. 11, T. 20 N., R. 16 W. Began drilling June, 1908. Shut down since January, 1909. Well was never completed.

Reliance No. 1; SE. ¼ NW. ¼ NW. ¼ NW. ¼ sec. 7, T. 20 N., R. 15 W. Formerly called Richardson No. 1 on the R. L. Pitts tract. Began drilling January, 1907. Was a gasser from October to December, 1907, from the 2,200-foot stratum. A blowout occurred and at present the well is a salt-water blower.

Reliance No. 2; NW. ¼ NW. ¼ sec. 7, T. 20 N., R. 15 W. Drilling November 17, 1907, to April 27, 1908. After bailing, while the 2½-inch wash pipe was being withdrawn, the well came in as a 25,000,000-foot gasser. In the confusion the 2½-inch pipe fell into the hole. All of it was got out but the last five joints. When bailed in again it came in as a 25-barrel well and a 15,000,000 to 20,000,000 foot gasser. In a few days the gas decreased and the oil increased in volume, and on June 1, 1908, the well was yielding 12,000,000 to 15,000,000 cubic feet of gas and 175 barrels of oil. It is still a good producer.

Reliance No. 3, Pitts; SW. ¼ NE. ¼ SW. ¼ NW. ¼ sec. 7, T. 20 N., R. 15 W. Drilling December, 1908, to February, 1909; 75 barrels.

Richardson No. 1, Pitts. See Reliance No. 1.

Richardson No. 2, Pitts. See Reliance No. 2.

D. C. Richardson No. 3; SW. ¼ SE. ¼ NE. ¼ NW. ¼ sec. 32, T. 20 N., R. 15 W., on Pine Island, 600 feet northwest of Texla No. 1. Shale and sand at 1,820 feet; at 2,085 feet a blowout occurred, and on May 19, 1907, hole fell in 250 feet. At present the well is a salt-water blower with a depth of about 1,750 feet.

Richardson No. 4; SW. ¼ NE. ¼ NW. ¼ sec. 32, T. 20 N., R. 15 W. Shale and sand with oil at 2,068 feet. A 300-barrel well, November, 1907.

Richardson No. 5; SE. ¼ SE. ¼ NE. ¼ NW. ¼ sec. 32, T. 20 N., R. 15 W. Completed October 25, 1908. A 3,900-barrel well. On October 27, 1908, it went to mud and sand, and then stopped producing.

Richardson No. 6; SW. ¼ SW. ¼ NE. ¼ NW. ¼ sec. 32, T. 20 N., R. 15 W. A derrick only on Pine Island.

Richardson No. 1, Guy; NE. ¼ sec. 32, T. 20 N., R. 15 W. Drilling began January, 1909.

Richardson No. 1, Nunnelley & Richardson; SE. ¼ SE. ¼ sec. 25, T. 21 N., R. 16 W. Began drilling December, 1908.

Richardson No. 1, Richardson; SE. ¼ NW. ¼ SW. ¼ SW. ¼ sec. 1, T. 20 N., R. 16 W. Began drilling December, 1908. A dry hole January, 1909. Shot with nitroglycerine without effect.

Rogers No. 1, Rogers, at Lewis; sec. 24, T. 21 N., R. 16 W. At 2,000 feet gas began to escape through cracks in the ground and finally derrick and all fell in. Estimated capacity 40,000,000 cubic feet of gas in August, 1908. This well became a salt-water blower, but was successfully killed by Brown Brothers, the drillers. In December, 1908, operations were commenced to go deeper.

Rogers No. 2, Rogers, at Lewis; sec. 24, T. 21 N., R. 16 W. Drilling July to September 6, 1908. A big gasser (40,000,000 cubic feet) at 1,035 feet.

Rogers No. 3, Rogers, at Lewis; SW. ¼ sec. 24, T. 21 N., R. 16 W. Began drilling December, 1908.

Savage Brothers & Morricell. See Caddo Lake Oil and Pipe Line Company.

Savage & Richardson No. 1; One-fourth mile north of Savage Brothers & Morricell well, in the northeast corner of Caddo town site. A 38-foot oil sand was struck at 2,280 feet; the oil was of 27° gravity Baumé. The well was pumped at the rate of 40 barrels and turned to salt water, November 18, 1906.

Savage & Richardson No. 2; 500 feet northwest of Producers No. 1, Heilperin & Liebman, November 18, 1906.

Savage No. 2; NW. ¼ NW. ¼ sec. 1, T. 20 N., R. 16 W. Estimated at 2,200 feet, June 5, 1907.

School No. 1, McGuire; SW. ¼ SW. ¼ NW. ¼ SW. ¼ sec. 16, T. 20 N., R. 15 W. A 20,000,000-foot gasser at 805 feet, June 19, 1907.

School No. 2, McGuire; SE. ¼ SE. ¼ SW. ¼ NW. ¼ sec. 16, T. 20 N., R. 15 W. A 20,000,000-foot gasser at 825 feet, August 19, 1907.

Shreveport Petroleum Company No. 1; 1,500 feet northwest of the center of sec. 1, near Savage No. 2. Oil was found at 2,200 feet in June, 1907.

Staiti No. 1; SW. ¼ sec. 31, T. 20 N., R. 15 W. Mooringsport, on the Wrad tract. Began drilling February, 1909.

St. Louis and Southwestern Oil Company, near Mooringsport. Twisted off at 800 feet, January, 1906.

St. Louis and Pipe Line Company; south of Mooringsport. Drilled to 900 feet and shut down.

Texla No. 1; NW. ¼ NE. ¼ SW. ¼ NW. ¼ sec. 32, T. 21 N., R. 15 W., on Pine Island. The well that opened this district. A 275-barrel oil well plus 20 per cent salt water, December, 1906. When slightly deepened the well flowed by head 150 to 200 barrels of 20° gravity Baumé oil, The well was deepened to 2,264 feet and developed salt water. The casing was pulled August, 1907.

Texla No. 2; NW. ¼ SW. ¼ NE. ¼ sec. 32, T. 21 N., R. 15 W., on Pine Island, 300 feet of No. 1. Abandoned at 2,300 feet, June 5, 1907, because the well developed salt water. The casing was pulled and the hole abandoned.

Texla No. 3; NE. ¼ SE. ¼ NW. ¼ sec. 32, T. 21 N., R. 15 W., on Pine Island. Drilling April to August 20, 1908. Yield 300 barrels net, with some salt water.

Thompson No. 1. See McCormick No. 2.

Trees & Benedum No. 1. See Benedum & Trees No. 1.

Trees No. 1, Dixon. Drilling August to November 6, 1908. A dry hole.

Trees No. 2, Dixon. Shut down through June and July, 1908, because of high water.

Trees No. 1, S. A. Guy. Derrick only.

Trees No. 1, Heilperin & Leibman; NE. ¼ NE. ¼ NW. ¼ sec. 32, T. 21 N., R. 15 W., on Pine Island. Drilling June to November 6, 1908. A dry hole.

Trees No. 3, Ruddersdorf; SE. ¼ SE. ¼ NE. ¼ NW. ¼ sec. 11, T. 20 N., R. 15 W. Derrick only.

J. C. Trees Oil Company No. 1; NW. ¼ sec. 27, T. 21 N., R. 16 W., on the W. P. Stiles tract west of Lewis station. Brown Brothers, drillers. Completed December 6, 1908. Yield 50 barrels of oil with a large amount of gas at 1,060 feet, January 20, 1909. The hole was deepened and by pumping with a standard rig 300 barrels of oil and 300 barrels of water were produced daily. In February, 1909, the daily capacity was stated to be 125 barrels. This well is the farthest west in the field.

Vivian Oil Company No. 1, Childs. Owned by the Dawes Company. Drilling November to December 18, 1908. A 75-barrel well with a small amount of water.

Vivian Oil Company No. 1, Edwards. Owned by the Dawes Company. Drilling August to September, 1908. A 25-barrel well.

Below are given some logs of representative wells in the Caddo field.

Log of Filer well No. 1.

[Received from Mr. Plumb.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	75	75	Gumbo	29	1,069
Sand	5	80	Do	51	1,120
Dark clay	20	100	Shale	80	1,200
Rock	4	104	Lime, soft	100	1,300
Clay	11	115	Lime, hard	140	1,440
Rock	3	118	Rock	10	1,450
Shale	57	175	Lime, soft	80	1,530
Rock	2	177	Rock	10	1,540
Shale	148	325	Lime, soft	25	1,565
Rock	3	328	Shale	115	1,680
Shale	172	500	Gumbo	80	1,760
Rock	4	504	Shale, hard	115	1,875
Gumbo	121	625	Rock	5	1,880
Rock	5	630	Shale	110	1,990
Gumbo	50	680	Rock	8	1,998
Shale, hard	20	700	Shale	52	2,050
Shale, soft; some gas	20	720	Rock	10	2,060
Shale and gumbo	90	810	Shale	75	2,135
Rock	80	890	Rock	5	2,140
Shale, hard	60	950	Shale	100	2,240
Gumbo	40	990	Good oil sand	12	2,252
Shale	50	1,040			

Log of Gulf Refining Company's Hostetter well No. 1.

[Received from B. G. Dawes.]

	Thickness.	Depth.
	Feet.	*Feet.*
Clay and shale	29	29
Hard, dark sand rock	2	31
Light gumbo and shale	74	105
Dark lime rock	3	108
Light gumbo	15	123
Sand, rock, and shell	1	124
Blue shale	176	300
Sand rock, shells, and shale	10	310
Blue shale and light gumbo	338	648
Brown shale; much gas	27	675
Shale and gumbo	131	806
Soft sand rock; gas	2	808
Brown sandy shale	7	815
Hard brown shale, to top of Nacatoch or "Caddo gas" sand	5	820
(Well bailed here, showing a capacity of about 2,500,000 cubic feet of gas per day, but salt water flooded the hole at once.)		
Gas sand	8	828
Hard brown shale	32	860
Sand rock, with gas	2	862
Hard brown shale, soft at base	38	900
Light gumbo, mixed with white shale	258	1,158
Light lime rock	13	1,173
Gumbo and blue shale	148	1,320
Hard, white lime rock and broken shale	210	1,530
Light gumbo, mixed with kaolin and white shale	115	1,645
Brown shale, mixed with pyrite	2	1,647
Brown shale	14	1,661
Brown shale and pyrite	3	1,664
Gumbo, turning to shale	59	1,723
Hard brown shale	19	1,742
Coarse brown packed sand	8	1,750
Light brittle gumbo	30	1,780
Coarse brown packed sand	6	1,786
Light gumbo and blue shale	44	1,830
Coarse brown packed sand, almost sandstone	10	1,840
Stiff blue shale	68	1,908
Brown packed sand	7	1,915
Blue shale, turning brown	89	2,004
Stiff blue shale	96	2,100
Light-brown shale	105	2,205
Light-colored gritty sandstone, with gas and oil	4	2,209

Log of McCormick's Shreveport brickyard well.

[Received from W. McCormick.]

	Thickness.	Depth.
	Feet.	*Feet.*
Gray clay	20	20
Lignite	4	24
Gray shale	60	84
Shale	16	100
Shale and pipe clay	80	180
Gray shale	120	300
Brown shale	100	400
Dark shale	200	600
Shale and rock	200	800
Gumbo (pyrite in the last few days)	160	960
Rock	2	962
Shale	138	1,100
White rock, with shale mixed	500	1,600
Clay and gumbo	200	1,800
Sand rock at	....	1,800
Rock and shale	100	1,900
Gumbo and shale	100	2,000

Log of B. G. Dawes and Gulf Refining Company's Posey well No. 1, Vivian, La.

[Received from B. G. Dawes.]

	Thickness.	Depth.
	Feet.	*Feet.*
Clay and yellow sand	197	197
Blue sand	53	250
Shale	8	258
Rock	3	261
Water sand, blue and yellow	209	470
Lime rock	1	471
Rock	18	489
Sand	9	498
Bowlders	40	538
Bowlders, with soft places between	12	550
Rock	5	555
Rocks with soft places between	4	559
Rock	6	565
Rock and sands	35	600
Rock with soft streaks	75	675
Gumbo	21	696
Soft rock and sand	1	697
Gumbo	29	726
Do	141	867
Bowlders	1	868
Gumbo	15	883
Bowlders	2	885
Gumbo	14	898
Bowlders	1	899
Black gumbo	13	912
Black shale	20	932
Shale	64	996
Rock with gas	2	998
Rock with pyrite	7	1,005
Gumbo	1	1,006
Rock	1	1,007

Log of B. G. Dawes and Gulf Refining Company's Posey well No. 1, Vivian, La.—Continued.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Blue shale with hard streaks	11	1,018	Gray rock	1	1,136
Bowlders	2	1,020	Blue shale	29	1,165
Shale	5	1,025	Rock sand	6	1,171
Bowlders	2	1,027	Blue shale	6	1,177
Blue shale	4	1,031	Rock with soft streaks	48	1,225
Hard rock	1	1,032	Shale	63	1,287
Dark gumbo	12	1,044	Gray rock with sand	2	1,289
Rock	2	1,046	White shale	40	1,329
Gumbo	8	1,054	Sand rock	5	1,334
Blue shale	48	1,102	Blue shale	22	1,356
Gumbo	6	1,108	Gray rock, hard	4	1,360
Gray rock with sand	5	1,113	Gumbo	37	1,397
Bastard shale	11	1,124	Bowlder	1	1,398
Gray rock with sand	1	1,125	Tough blue gumbo	9	1,407
Dark shale	10	1,135			

Log of B. G. Dawes and Gulf Refining Company's Heilperin well No. 1, Vivian, La.

[Received from B. G. Dawes.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Surface clay	7	7	Black gumbo	8	332
White sand	21	28	Gray hard rock	4	336
Quicksand	12	40	Blue shale	6	342
Gray sand	10	50	Gray rock	1	343
Water gravel	6	56	Bastard gumbo	12	355
Dark gumbo	5	61	Gray rock	1	356
Dark water sand	24	85	Dark gumbo	20	376
Hard packed sand	17	102	Dark shale	24	400
Water sand	53	155	Gumbo	14	414
Hard rock	5	160	Shale	10	424
Blue sand	21	181	Tough gumbo	277	701
Gray rock	2	183	Shale	6	707
Dark sand	4	187	Gumbo	131	838
Soft rock	1	188	Shale with oil	22	860
Sand	4	192	Tough gumbo	8	868
Sandy rock	1	193	Blue shale	12	880
Blue sand	51	244	Dark gumbo	62	942
Rock	2	246	Gypsum, kaolin, shale, or limestone; show of oil	18	960
Rock, gray and hard	3	249	Blue gumbo	41	1,001
Blue sand	18	267	Sandy shale	9	1,010
Bastard gumbo	13	280	Black gumbo	52	1,062
Blue shale	18	298	Rock	1	1,063
Tough dark gumbo	13	311	Rock with gas	4	1,067
Bowlders	2	313	Gas sand	30	1,097
Dark shale	11	324			

Log of Heywood No. 1 well, fee.

[Received from H. H. Jones, driller.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay, variegated, soft	80	80	Rough, limelike rock with gas	10	830
Bluish sand, water bearing	10	90	Dry sand rock, with gas and oil smell	34	864
Clay, dark, soft	50	140	Rough lime rock	5	869
Hard dark rock	2	142	Dry sand rock, with oil and gas	61	930
Dark soft clay	8	150	Hard rock	2	932
Hard dark rock	3	153	Sand rock; gas from 820 to 940 feet	8	940
Gumbo and shale, dark, full of bowlders	447	600	Shales, with streaks of gumbo	39	979
Gumbo and dark shales	110	710	Rock	2	981
Shale, dark, with persistent gas	10	720	Shale and gumbo with hard streaks	163	1,144
Gumbo, dark and very tough	100	820			

Log of Heywood No. 1 well, fee—Continued.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Chalk, white and soft	11	1,155	Shale and dark gumbo	118	2,130
Dark gumbo	53	1,208	Rocky, with pyrite and shells	13	2,143
Dark shale	21	1,229	Red and dark shale	37	2,180
Dark gumbo	43	1,272	Blue shale	16	2,196
			Rock	2	2,198
Chalk, clayey to white; oil from 1,470 to 1,520 feet	328	1,600	Soft rock	2	2,200
Black rocky gumbo	100	1,700	Hard shale	24	2,224
Black sandy gumbo	80	1,780	Oil shale	3	2,227
Rock with some pyrite	5	1,785	Hard shale	5	2,232
			Oil shale	4	2,236
Coarse variegated sand, with oil smell	13	1,798	Hard shale	3	2,239
			Rock	3	2,242
Rock, in streaks sandy, and some pyrite	62	1,972	Brittle rock	10	2,252
Gumbo and shale	112	1,972	Shale	5	2,257
Tough gumbo	40	2,012			

Log of Blanchard No. 1 well, Graham.

[Received from A. G. Curtis.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Red and yellow clay	50	50	Shale and gumbo mixed	200	1,530
Water sand	25	75	White rock or shale	218	1,748
Gray packed sand	50	125	Gumbo	132	1,800
Gumbo and shell rock	30	155	Shale with streaks of shell rock	20	1,900
Blue shale	29	184	Shale	63	1,963
Shale and iron concretions	56	240	Hard sand rock	5	1,968
Shale and gumbo	81	321	Sand rock with shells	90	2,058
Shale rock and gumbo	80	401	Very sticky gumbo	32	2,090
Shell rock	29	430	Blue shale	92	2,182
Shell and gumbo	47	477	Shells of sand rock, with oil	11	2,193
Shale	98	575	Blue shale	87	2,280
Rock	4	579	Hard gumbo, shelly	11	2,291
Shell	10	589	Hard rock	1	2,292
Shell rock	89	678			
			Blue shale and white clay, small shells	12	2,304
Shale and gumbo; shell rock at 684 feet	6	684			
Blue shale; first gas	16	700	Shale, with small shells and salt water	11	2,315
Blue shale, with oil and gas	50	837	Shale with hard streaks	26	2,341
Blue shale	87	837	Brown and blue shale	4	2,345
Rock	3	840	Sand rock	5	2,350
Tough gumbo	95	935	Red and blue shale	20	2,370
Shale and gumbo	95	1,030	Sand rock	10	2,380
Hard rock	8	1,389	Red and blue shale	30	2,410
Hard shale with shell rock	31	1,006	Shale; very thin rock at 2,425 feet	15	2,425
Rock	106	1,175	Red and blue shale	5	2,430
Solid gumbo	155	1,330	Sand rock breaks	10	2.440

Log of Blanchard No. 1 well, Surrey.

[Record received from A. G. Curtis.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sand and red clay	63	63	Shale, gumbo, rocks	40	460
Shales and rocks	117	180	Shale and rock	115	575
Gumbo and rocks	30	210	Shale	95	670
Gumbo and shale	30	240	Rock, shelly	15	685
Shale	20	260	Shale	20	705
Shale and gumbo	80	340	Gumbo	30	735
Shale	60	400	Shale	45	780
Rock at	....	400	Gumbo	10	790
Shale	20	420	Shale	12	802

Log of Blanchard No. 1 well, Surrey—Continued.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Shale	12	802	Gumbo	30	1,710
Rock	5	807	Shale	40	1,750
Gas rock	5	812	Gumbo and shale	25	1,775
Shale	6	818	Sand rock	60	1,835
Shelly; gas from 820 to 845 feet	27	845	Gumbo, with some gas	90	1,925
Rock	1	846	Gumbo	25	1,950
Shale	18	864	Sandy shale with hard streaks	25	1,975
Sandy shale rock	2	866	Hard sandy shale	25	2,000
Shale	54	920	Hard sandy shale, with streaks of gumbo	100	2,100
Sandy shale	10	930	Shale	6	2,106
Gumbo	35	965	Gumbo	17	2,123
Hard shale	25	990	Blue shale	12	2,135
Gumbo	25	1,015	Gray shale (white)	9	2,144
Shale	20	1,035	Brown shale	4	2,148
Gumbo, tough	40	1,075	Blue shale; gas rock last 6 feet	17	2,165
Gumbo and shale	105	1,180	Blue shale, hard, white	6	2,184
Shale	20	1,200	Blue shale, gas rock	16	2,200
Gumbo and shale, turning white at base	60	1,260	Soft brown shale	15	2,215
White shale, shelly, with tough streaks and show of oil and gas	80	1,340	Hard shale	5	2,220
White formation	80	1,420	White shale	5	2,225
White tough formation	50	1,470	Dark shale	5	2,230
Shale and shelly	80	1,550	Red, brown, and blue shale	13	2,243
Gumbo and shale; some gas	60	1,610	Blue shale, sandy	7	2,250
Gumbo	30	1,640	Gray shale	4	2,254
Gumbo and shale	40	1,680	Brown shale	1	2,255
			Oil-bearing beds	2½	2.257½

Log of Caddo Gas and Oil Company's Hostetter No. 1 gas well.

[Received from B. G. Dawes.]

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Brown and yellow clay	15	15	Soft sand rock shell	2	377
Gumbo and hard blue shale	11	26	Gumbo	45	422
Gray lime shale	2	28	Hard sand rock	3	425
Soft blue shale	24	52	Hard tough gumbo	65	490
Gray hard lime shell	1	53	Soft sand rock	3	493
Gumbo and soft blue shale	27	80	Gumbo and light-blue shale	144	637
Gray hard lime shell	2	82	Kaolin, white shale, or gypsum	11	648
Soft blue shale	43	125	Soft sand rock (2,500,000 to 3,000,000 foot gasser)	9	657
Gray hard lime shell	3	128	Kaolin or white shale, sandy at base	10	667
Gumbo, hard and stiff	32	160	Hard stiff gumbo	91	758
Rock shell, sandy and soft	2	162	Hard sand rock	3	761
Gumbo, blue and hard	58	220	Gumbo with sandy shale at base	16	777
Sand rock, with gas	2	222	Hard sandy shale	3	780
Stiff blue shale	58	280	Caddo gas sand, rather hard, light colored, very sharp and gritty, with much gas	3½	783½
Soft sand rock	3	283			
Sandy brown shale, with gas	27	310			
Hard sand rock	1	311			
Blue hard gumbo	64	375			

Log of Broussard No. 1 well.

[Received from B. G. Dawes.]

	Thickness.	Depth.
	Feet.	*Feet.*
Joint and red clays	65	65
Water sand	7	72
Rock shell	2	74
Blue shale and gumbo, with rock shells	316	390
Hard dark shale. with gas	15	405
Blue shale and brittle gumbo, with kaolin shale at base	342	747
Caddo gas sand, broken with shale; gas	98	845
Hard shale and gumbo	15	860
Broken formation with coarse salt-water gravel at base	25	885
Blue shale, hard, with rock shells and gumbo	120	1,005
Kaolin shale beads, then blue shale	170	1,175
Kaolin shales, with some blue shale and sand; gas and oil from 1,360 to 1,520 feet	360	1,535
Bastard lime and kaolin shale	85	1,620
Blue hard shale	30	1,650
Blue shale and gumbo	50	1,700
Blue shale turning to soft brown shale	98	1,798
Bastard lime rock, with sandy shale in places; gas	95	1,893
Light shale	15	1,908
Big gumbo beads	62	1,970
Blue shale, hard at base	85	2,055
Kaolin shale to light shale, hard	15	2,070
Hard kaolin shale	12	2,082
Kaolin and sandy shale, with gas	18	2,100
Broken hard sand rock with sandy shale layers	12	2,121
Dark sandy shale, with oil and gas.	18	2,130
Loose soft blue shale	5	2,135
Hard rock	1	2,136
Sandy shale, with kaolin and a little pyrite, hard at base; gas and oil	38	2,174
Sandy shale, with oil	23	2,197
Fine sand, with oil	3	2,200
Sandy shale, red at base	3	2,203
Red shale, turning light	15	2,218
Mixed blue and red shale	6	2,224
Blue shale, sandy at base	7	2,235
Sandy shale, with oil	2	2,237
Mixed oil sand and dark shale, hard; good oil showing	2	2,239

Log of well northwest of Plaindealing, La.

[Received from G. E. Gilmer.]

	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	40	40
Lignite	2	42
Yellow water sand	10	52
Clay	8	60
White water sand (artesian)	140	200
Sandstone	2	202
Black packed sand	493	695
Shale	300	995
Rotten shale and shells	200	1,195
Tough blue gumbo	420	1,615
White chalky rock, hard, with gas.	8	1,623
Lime rock, with beds of sandy shale	364	1,987
Salt-water sand, with gas	110	2,097
Sandy shale, with oil	106	2,203
Rotten shells	20	2,223
Rotten shale with shells	260	2,483
White chalky rock	45	2,528
Shale	4	2,532
White hard chalky rock	4	2,536
Rotten shale with shells	114	2,650
Shells	10	2,660
Rotten shale with shells	17	2,677
Rock	29	2,706

Gas found at 390, 1,220, 1,628, 2,000, and 2,700 feet. Oil found at 1,220, 1,630, 2,150, and 2,700 feet.

Log of Caddo Gas and Oil Company's Noel well No. 2, Mooringsport.

[Received from S. S. Hunter.]

	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	20	20
Water sand	15	35
Blue sand	35	85
Rock	1	86
Blue shale	19	105
Rock	1	106
Shale	69	175
Rock	1	176
Blue shale	345	521
Rock	1	522
Gumbo	389	911
Gas sand	19	930
Salt-water sand	8	938
Gumbo and shale	562	1,500
White sand	45	1,545
Rock	1	1,546
Gumbo	57	1,603
Rock	8	1,611
Gumbo and shale	107	1,718
Gumbo, hard	217	1,935
Rock	1	1,936
Salt-water sand	14	1,950
Gumbo and shale	71	2,021
Rock	2	2,023
Salt-water sand, with gas	12	2,035
White shale	429	2,464

ALTITUDES IN THE CADDO FIELD.

In determining the stratigraphic relations of the oil and gas horizons in any region it is of the utmost importance to know the relative elevations at the mouths of the wells in that region. With that end in view the following dictionary of altitudes has been compiled. From any bench mark named in the list below it will be a comparatively easy task to run a line of levels to a near-by well or to estimate with a fair degree of accuracy the elevation of any desired point in the field. During the fall of 1908 the accompanying partial list of elevations of the wells in the Caddo oil field was obtained, with the assistance of Mr. James McDonough, of Mooringsport, La. The list of elevations of bench marks is taken from the Louisiana Geological Survey's report for 1905 (Bulletin No. 1), part 2, A dictionary of altitudes in northern Louisiana, by A. C. Veatch.

Bench marks in the Caddo field.

[NOTE.—The elevations given below vary greatly in accuracy, and they have been divided roughly into the following classes: P, Precise levels of the United States Engineer Corps, United States Coast and Geodetic Survey, and United States Geological Survey. E, Engineers' levels—levels run by United States engineers, but not classed by them as precise; in general, more accurate than railroad levels. R, Railroad levels. As there is no economic need for extreme precision in elevations in railroad construction, these levels, as a rule, may be regarded as only approximate. The error, however, is relatively small.]

Location.	Authority.[a]	Elevation.
		Feet.
Arkansas-Louisiana state line; rail end bench, 9 feet west of milepost 516	K. C. S.	P 228.80
Blanchard, 4 miles north of; rail end bench, 15 feet west of first telegraph pole north of milepost 544.	K. C. S.	P 285.33
—— 3.5 miles north of; rail end bench, 60 feet southwest of second telegraph pole south of milepost 544.5.	K. C. S.	P 305.84
—— 3 miles north of; rail end bench, 60 feet southwest of milepost 545	K. C. S.	P 292.60
—— 2.5 miles north of; rail end bench, 70 feet southwest of milepost 545.5	K. C. S.	P 286.57
—— 2 miles north of; rail end bench, 15 feet northwest of first telegraph pole south of milepost 546.	K. C. S.	P 283.77
—— 1.5 miles north of; rail end bench, 12 feet west of milepost 546.5	K. C. S.	P 270.17
—— 1 mile north of; rail end bench, 12 feet west of milepost 547	K. C. S.	P 244
—— 0.5 mile north of; rail end bench, 10 feet west of milepost 547.5	K. C. S.	P 226.43
—— rail end bench, 12 feet west of milepost 548	K. C. S.	P 227.91
—— depot; top of rail, at center	K. C. S.	R 227
—— 0.5 mile south of; rail end bench, 30 feet northwest of milepost 548.5	K. C. S.	P 223.83
—— 1 mile south of; rail end bench, 25 feet west of milepost 549	K. C. S.	P 213.19
—— 1.5 miles south of; rail end bench, 25 feet northwest of milepost 549.5	K. C. S.	P 211.65
—— 2 miles south of; rail end bench, 20 feet west of milepost 550	K. C. S.	P 203.96
—— 2.5 miles south of; rail end bench, 40 feet north of first telegraph pole north of milepost 550.5.	K. C. S.	P 201.50
—— 3 miles south of; rail end bench, 30 feet southwest of third telegraph pole south of milepost 551.	K. C. S.	P 187.84
—— 3.5 miles south of; rail end bench, 95 feet south of milepost 551.5	K. C. S.	P 186.36
—— 4 miles south of; rail end bench, 20 feet southwest of milepost 552	K. C. S.	P 195.15
—— 4.5 miles south of; rail end bench, 15 feet northwest of milepost 552.5	K. C. S.	P 195.86
—— 5 miles north of; rail end bench, 75 feet north of first telegraph pole north of milepost 553.	K. C. S.	P 191.06
—— 5.5 miles south of; rail end bench, 85 feet north of milepost 553.5	K. C. S.	P 186.56
—— 6 miles south of; rail end bench, 25 feet northwest of milepost 554	K. C. S.	P 183.68
Caddo Lake, Kansas City Southern Ry. crossing; bridge	K. C. S.	R 199
—— high water	K. C. S.	R 190
—— bed	K. C. S.	R 170
Cross Lake, Kansas City Southern Ry. bridge; top of rail	K. C. S.	R 182
—— high water	K. C. S.	R 178
—— bed of lake	K. C. S.	R 160
—— bed of channel	K. C. S.	R 155
Ferry Lake, Jeters Landing; pipestone bench near northeast corner of deserted cabin.	U. S. E.	P 197.246
—— Mooringsport; pipestone bench on north side of C. S. Croon's store	U. S. E.	P 183.135
Hendersons' Mills, Caddo Lake; pipestone bench near northwest corner of deserted house.	U. S. E.	P 244.352

[a] K. C. S., Kansas City Southern Railway; U. S. E., United States Engineers; V., S. & P., Vicksburg, Shreveport and Pacific Railway; H. & S., Houston and Shreveport Railroad; T. & P., Texas and Pacific Railway; M., K. & T., Missouri, Kansas and Texas Railway.

Bench marks in the Caddo field—Continued.

Location.	Authority.	Elevation.
		Feet.
Jeters Landing, Ferry Lake; pipestone bench near northeast corner of deserted cabin.	U. S. E	P 197.246
Lewis, 1.4 miles north of; rail end bench, at milepost 530.5	K. C. S	P 208.91
—— 0.9 mile north of; rail end bench, 8 feet west of milepost 531	K. C. S	P 205.93
—— 0.4 mile north of; rail end bench, 15 feet northwest of milepost 531.5	K. C. S	P 201.61
—— 0.1 mile south of; rail end bench, at milepost 532	K. C. S	P 193.87
—— 0.6 mile south of; rail end bench, 40 feet north of milepost 532.5	K. C. S	P 187.74
—— 1.1 miles south of; rail end bench, 15 feet west of milepost 533	K. C. S	P 189.49
Mooringsport, 2.8 miles north of; rail end bench, 70 feet north of first telegraph pole south of milepost 536.5.	K. C. S	P 202.55
—— 2.3 miles north of; rail end bench, 15 feet west of first telegraph pole north of milepost 537.	K. C. S	P 195.05
—— 1.8 miles north of; rail end bench, 50 feet southwest of second telegraph pole south of milepost 537.5.	K. C. S	P 209.87
—— 1.3 miles north of; rail end bench, 15 feet west of milepost 538	K. C. S	P 192.73
—— 0.8 mile north of; rail end bench, 7 feet west of first telegraph pole north of milepost 538.5.	K. C. S	P 200.12
—— 0.3 mile north of; rail end bench, 15 feet west of first telegraph pole south of bridge "B 539."	K. C. S	P 201.32
—— pipestone bench on north side of C. S. Croon's store	U. S. E	P 183.135
—— depot, top of rail at center	K. C. S	R 197
—— 0.2 mile south of; bench mark on northeast corner of north pedestal, east pair, water tank.	K. C. S	P 194.33
—— 0.7 mile south of; rail end bench, 45 feet left of track opposite milepost 540	K. C. S	P 206.05
—— 1.2 miles south of; rail end bench, 20 feet west of first telegraph pole north of milepost 540.5.	K. C. S	P 195.06
—— 1.7 miles south of; rail end bench, 20 feet west of milepost 541	K. C. S	P 190.87
—— 2.2 miles south of; rail end bench, 25 feet west of milepost 541.5	K. C. S	P. 198.23
—— 2.7 miles south of; rail end bench, 20 feet west of milepost 542	K. C. S	P 207.53
—— 3.2 miles south of; rail end bench, 15 feet west of milepost 542.5	K. C. S	P 238.50
—— 3.7 miles south of; rail end bench, 15 feet west of milepost 543	K. C. S	P 261.90
—— 4.2 miles south of; rail end bench, 20 feet southwest of milepost 543.5	K. C. S	P 277.56
Myrtis, 0.8 mile north of; rail end bench, 15 feet north of fifth telegraph pole south of milepost 522.	K. C. S	P 215.86
—— 0.3 mile north of; rail end bench, 15 feet southwest of second telegraph pole north of milepost 522.5.	K. C. S	P 198.12
—— platform, top of rail, at south end	K. C. S	R 211
—— 0.2 mile south of; rail end bench, 10 feet west of milepost 523	K. C. S	P 207.78
—— 0.7 mile south of; rail end bench, 15 feet west of milepost 523.5	K. C. S	P 221.64
—— 1.2 miles south of; rail end bench, 75 feet north of milepost 524	K. C. S	P 212.14
—— 1.7 miles south of; rail end bench, 18 feet west of milepost 524.5	K. C. S	P 227.35
—— 2.2 miles south of; rail end bench, 17 feet west of milepost 525	K. C. S	P 234.50
Oil City, 1.6 miles north of; rail end bench, 45 feet northeast of milepost 533.5	K. C. S	P 181.61
—— 1.1 miles north of; rail end bench, 12 feet west of milepost 534	K. C. S	P 190.72
—— 0.6 mile north of; rail end bench, 15 feet west of milepost 534.5	K. C. S	P 194.73
—— 0.1 mile north of; rail end bench, 15 feet west of milepost 535	K. C. S	P 196.42
—— 0.4 mile south of; rail end bench, 18 feet west of first telegraph pole north of milepost 535.5.	K. C. S	P 205.28
—— 0.9 mile south of; rail end bench, 60 feet north of milepost 536	K. C. S	P 206.15
Plaindealing; pipestone bench, 325 feet north of depot, 60 feet west of track	U. S. E	P 260.415
Roberta; root bench in red oak west of track, 100 feet south of wagon road crossing.	U. S. E	P 320.842
Shreveport, 4 miles north of; rail end bench, 15 feet west of milepost 555	K. C. S	P 163.41
—— 3.5 miles north of; rail end bench, 60 feet north of third telegraph pole south of milepost 555.5.	K. C. S	P 185.78
—— 3 miles north of; rail end bench, 45 feet left of track opposite milepost 556	K. C. S	P 189.79
—— 2.5 miles north of; rail end bench, 85 feet north of third telegraph pole south of milepost 556.5.	K. C. S	P 208.34
—— 2 miles north of; rail end bench, 20 feet southeast of second telegraph pole south of milepost 557.	K. C. S	P 230.43
—— 1.5 miles north of; bench mark on 0.75 inch rod 1 foot west of west side of roundhouse.	K. C. S	P 249.124
—— rail end bench, 15 feet west of first telegraph pole north of south head block of Y.	K. C. S	P 219.51
—— rail end bench, 25 feet northwest of third telegraph pole south of milepost 559.	K. C. S	P 206.63
—— pipestone bench in yard of post-office	U. S. E	P 195.744
—— high water, 1892	U. S. E	E 176.70
—— zero, United States Engineers' gage	U. S. E	E 140.99
—— Vicksburg, Shreveport and Pacific Ry. bridge; west end, top of rail	V., S. & P.	R 189.3
—— "X" on lower course of top stones on south side of west abutment Vicksburg, Shreveport and Pacific Ry. bridge.	U. S. E	P 181.800
—— highest point in; Hicks street east of Fairfield street	(*a*)	276
—— Texas and Pacific Ry. crossing	H. & S	R 228.
—— Missouri, Kansas and Texas Ry. crossing; top of rail	K. C. S	R 238.9
—— Texas and Pacific Ry. crossing; top of rail	K. C. S	R 238.3
—— Houston and Shreveport R. R. freight station, top of rail, center of	H. & S	R 234
—— Houston and Shreveport R. R. crossing, grade	K. C. S	R 234
—— bench mark on southwest corner stone of sill door, men's waiting room at union depot.	K. C. S	P 208.61
—— bench mark on southwest corner of brick foundation on first bent, south end of coal chute track.	K. C. S	P 247.55

[a] Map of Shreveport showing sewer-pipe system, November, 1900.

Bench marks in the Caddo field—Continued.

Location.	Authority.	Elevation.
		Feet.
Shreveport, bench mark on corner curb, north side of Jordon street, 20 feet right of track.	K. C. S.	P 243.86
—— junction, pipe under oak 68 feet right of track	T. & P.	R 230.28
—— 0.5 mile south of; rail end bench, 12 feet west of milepost 559.5	K. C. S.	P 202.64
—— 1 mile south of; rail end bench, 75 feet north of milepost 560	K. C. S.	P 203.02
—— 1.5 miles south of; rail end bench, 25 feet northwest of milepost 560.5	K. C. S.	P 214.88
—— 2 miles south of; rail end bench, 12 feet west of milepost 561	K. C. S.	P 225.01
—— 2.5 miles south of; rail end bench, 25 feet west of milepost 561.5	K. C. S.	P 210.52
—— 3 miles south of; rail end bench, 25 feet northwest of first telegraph pole north of milepost 562.	K. C. S.	P 219.04
—— 3.5 miles south of; rail end bench, 25 feet west of milepost 562.5	K. C. S.	P 206.17
—— 4 miles south of; rail end bench, 25 feet west of milepost 563	K. C. S.	P 203.30
—— 4.5 miles south of; rail end bench, 25 feet northwest of milepost 563.5	K. C. S.	P 202.67
Soda Lake, lower end of, right bank; pipestone bench at Albany Point in northeast corner of yard.	U. S. E.	P 222.868
—— upper end of, right bank; pipestone bench near northwest corner of deserted house at Henderson Mills.	U. S. E.	P 244.352
Texas-Louisiana line	M., K. & T.	R 261
Twelvemile Bayou, head of; right bank; pipestone bench at Albany Point in northeast corner of yard.	U. S. E.	P 222.868
Vivian, 1.2 miles north of; rail end bench, 20 feet northwest of milepost 525.5	K. C. S.	P 224.35
—— 0.7 mile north of; rail end bench, 12 feet west of milepost 526	K. C. S.	P 250.91
—— 0.2 mile north of; rail end bench, 65 feet south of first telegraph pole north of milepost 526.5.	K. C. S.	P 246.28
—— depot, at center, top of rail	K. C. S.	R 250.8
—— 0.3 mile south of; rail end bench, 12 feet west of milepost 527	K. C. S.	P 251.36
—— 0.8 mile south of; rail end bench, 8 feet west of milepost 527.5	K. C. S.	P 245.95
—— 1.3 miles south of; rail end bench, 10 feet southwest of second telegraph pole north of milepost 528.	K. C. S.	P 247.10
—— 1.8 miles south of; rail end bench, 15 feet west of second telegraph pole north of milepost 528.5.	K. C. S.	P 226.47
—— 2.3 miles south of; rail end bench, 20 feet west of milepost 529	K. C. S.	P 215.93
—— 2.8 miles south of; rail end bench, 20 feet west of second telegraph pole north of milepost 529.5.	K. C. S.	P 206.29
—— 3.3 miles south of, rail end bench, 45 feet north of milepost 530	K. C. S.	P 206.63

Elevations of wells in the Caddo field.

[D. F., derrick floor; T. P., top of pipe; G. L., ground level. Elevations in feet.]

Caddo Gas and Oil Company, Hostetter No. 4	D. F., 181.1; G. L., 178.9
Caddo Gas and Oil Company, Hostetter No. 3	T. P., 181.4; G. L., 179.4
Gulf Refining Company, Hostetter No. 1	T. P., 174.6
Gulf Refining Company, Hostetter No. 2	D. F., 174.0
Caddo Gas and Oil Company, Hostetter No. 1	G. L., 179
Caddo Gas and Oil Company, Gilbert No. 2 (oil)	D. F., 182.9
Caddo Gas and Oil Company, Gilbert No. 1 (oil)	D. F., 192.6; G. L., 189.6
Producers', Homestead No. 2	D. F., 206
Blanchard No. 3	D. F., 200.1
Producers', Homestead No. 1	D. F., 210.3
Caddo Gas and Oil Company, Noel No. 1	T. P. 221.1; G. L., 220.6
Caddo Gas and Oil Company, Noel No. 3	T. P., 222.7; G. L., 220.2
Caddo Gas and Oil Company, Noel No. 2	T. P., 260.8; G. L., 259.8
Blanchard No. 2	T. P. 208.5; G. L., 207.2
Producers' No. 1, Murray	D. F., 209.6
Blanchard No. 1	D. F., 204.9
Producers', Caddo Oil and Mining Company No. 8	D. F., 205
Blanchard No. 4	D. F., 206.6
Savage No. 1, Savage Brothers & Morricell, Shreveport Petroleum Company No. 1, Townsite	T. P., 202.4; D. F., 201.8
Caddo Gas and Oil Company, Offenhauser No. 4	D. F., 204.2
Caddo Gas and Oil Company, Offenhauser No. 2	D. F., 205.4
Big Four No. 1	T. P., 205.6

Caddo Gas and Oil Company, Offenhauser No. 3	T. P., 207.0;	D. F., 206.0
Producers' No. 1		D. F., 202.2
Big Four No. 2		D. F., 203.3
Caddo Gas and Oil Company, Gilbert No. 1 (gas)		G. L., 211.7
Caddo Gas and Oil Company, Gilbert No. 3 (gas)		T. P., 217.1
Caddo Gas and Oil Company, Gilbert No. 4 (gas)		G. L., 212.7
C. G. Dawes, Trustee No. 1		G. L., 209
C. G. Dawes, Trustee No. 2		D. F., 210.6
Broussard No. 1		D. F., 181.9
Broussard No. 2		D. F., 171.3
Reliance No. 2		D. F., 208.4
Filer No. 1	T. P., 215;	D. F., 214
Filer No. 2		D. F., 213.2
Caddo Gas and Oil Company, Gilbert No. 5 (Henning)		T. P., 191.5
Producers' No. 1, Murray, Colquitt & Hardy		D. F., 193.3
Producers' No. 2, Lane	T. P., 199.2;	D. F., 198.4
Evans No. 2, McGuire		T. P., 221.9
Producers' No. 2, Murray		D. F., 204
Caddo Gas and Oil Company, Smith No. 1		T. P., 203.9
Caddo Gas and Oil Company, Smith No. 5		T. P., 203.9
Producers' No. 1, T. M. Richardson	T. P., 205.9;	D. F., 203.2
Lillie No. 1	T. P., 202.1;	D. F., 201.6
Caddo Gas and Oil Company, Caddo Lake Oil and Pipe Line No. 1		D. F., 201.9
Producers', Caddo Oil and Mining Company No. 7	T. P., 208.8;	D. F., 205.9
Evans No. 3, McGuire	T. P., 220.1;	D. F., 217.9
Producers', Black Bayou No. 2	T. P., 215.1;	D. F., 214.3
Producers', Black Bayou No. 1		T. P., 210.6
Producers', Lane No. 1		D. F., 205.6
Producers', Riddersdorf No. 1		D. F., 204.1
Latex No. 1		G. L., 194.5
Latex No. 2	T. P., 198.6;	D. F., 198.1
Heywood No. 1		D. F., 198.1
Richardson No. 3 (Pine Island)		T. P., 181.6
Richardson No. 4 (Pine Island)		D. F., 181.0
Richardson No. 5 (Pine Island)		D. F., 178.8
Richardson No. 6 (Pine Island)		D. F., 181.4
Texla No. 1	T. P., 179.6;	D. F., 178.8
Texla No. 2		G. L., 174.8
Texla No. 3	T. P., 180.4;	D. F., 179.5
Dixon's Oil and Pipe Line No. 1 (Pine Island)		D. F., 179.9
Tree's No. 1, Heilperin & Liebman		D. F., 178.2
McCormick No. 1, Croom		D. F., 171.2
Broussard No. 1, Brown		D. F., 216
Caddo Gas and Oil Company, Hiner No. 1, Vivian		D. F., 246.2
B. G. Dawes and Gulf Refining Company, Posey No. 1, Vivian		D. F., 213
B. G. Dawes and Gulf Refining Company, Heilperin No. 1, Vivian		D. F., 285
Vivian Oil Company, Edwards No. 1		D. F., 250.2

EOCENE HORIZONS.

The few notes given under Lincoln, Vernon, and Sabine parishes, page 32, include practically all that is known regarding oil and gas at Eocene horizons in Louisiana.

About the saline domes and along marginal benches of the Sabine uplift the basal Eocene beds are possible sources of oil and gas. Practically no systematic development has been carried on in beds of this series, but some haphazard drilling has been done, as will appear from the details of wells given on pages 32–33.

QUATERNARY HORIZONS.

INTRODUCTORY REMARKS.

Gas escapements are of common occurrence and wide geographic distribution in the Quaternary areas about the lower Mississippi embayment, especially in Terrebonne Parish. Plate XXII, *B*, shows a typical gas escapement on Lake Felicity in the southeastern portion of the parish. Twenty miles to the west are others, that are notable for size and activity; still others occur in the Montegut region, 10 miles to the north.

Such wide distribution of notable gas escapements naturally suggests that there are in these areas deeply buried, broad structural features tending to favor the accumulation of hydrocarbons in areas of considerable lateral extent—in other words, that here the Caddo conditions are repeated in a general way in younger beds. There may be an area of considerable extent under which the beds of a certain age are much nearer the surface than they are in surrounding areas; that is, there may be a Terrebonne uplift corresponding in a way to the Sabine uplift, already described.

Corroborative of this supposition are the irregularities noted in intensity and direction of terrestrial magnetism in this part of the State, though so little has been done along this line of investigation that definite conclusions on such data can not yet be safely drawn.

Again, the fact that a well can be put down beside a large and persistent gas escapement and find below a depth of a hundred feet or so not a trace of oil or gas seems to indicate that here the gas is not coming up from the apex of a local saline dome. In rising toward the surface its course is determined by the perviousness of the beds it encounters, after moving laterally perhaps for considerable distances in nearly horizontal beds. In the saline domes it can not move far laterally owing to the general prevalence of impervious beds with strong quaquaversal dip.

Finally, Mr. I. N. Knapp, whose work furnishes the basis of nearly all that is known regarding the geology of Terrebonne Parish, suggests folds or slopes of considerable vertical and lateral dimensions when he maintains[a] that in well No. 7 (see fig. 20) he found the same streak of gravel with crinoid stems at a depth of 2,550 feet as in well No. 2 at 650 feet; and in No. 7 apparently the same shell streak with fresh-water individuals at 3,000 feet that occurred in No. 2 between 105 and 1,100 feet.

For the reasons above indicated the discussion of the gas and oil in Terrebonne Parish has been placed under the heading "Stratum oil and gas" and not under "Saline-dome oil and gas."

The most important developments in Terrebonne Parish are: (1) The well sunk by the H. G. Bush Petroleum Company near Montegut; (2) the Pickard and Heywood Brothers well on the Leo Lirette farm, described as "18 miles south of Houma;" (3) the five test wells put down by I. N. Knapp in various parts of the parish (see fig. 19); and (4) the Gulf Refining Company's well, near the Lirette (Pickard-Heywood) well.

WELLS AT MONTEGUT.

The following statements concerning the "Magenta" well of the Bush Petroleum Company were received from Mr. Bush, of New Orleans. They are contained in a typewritten copy of a report that seems to have been prepared by Prof. F. C. Thiele, then of Beaumont, Tex., though the report is not signed. The descriptive and chemical notes seem to be carefully written. The identifications of horizons and fossils are rarely correct, but are given exactly as received.

Log of "Magenta" well, Montegut.

	Thickness.	Depth.
	Feet.	*Feet.*
Buff-colored sand with clay and humus	20	20
Gray sand and clay, gas (mainly sulphureted hydrogen), salt water, films of iron oxide, shell fragments. Gas was struck at 30 feet	20	40
Gray sand with shell fragments and black iron oxide containing traces of earth wax. Oil showing	20	60
Light-brown clay and sand with shell fragments. At 90 feet pieces of clay and soft asphalt	40	100
Light-brownish clay with shell fragments	20	120
Light-gray sand with shell fragments, fragments of lignitized wood, water very salty	20	140
Light-gray sand containing pieces of dark and drab colored laminated clay, shell fragments and shell *Astarte smithvillensis*	20	160
Light-gray clayey sand, red iron oxide, thick pieces of metallic iron, shell fragments, strong salt water	20	180
Light-gray clayey sand, red iron oxide, shell fragments, strong salt water	20	200
Light-gray clayey sand, red iron oxide, shell fragments, salt water	20	220
Light-gray clay, fine white sand, very small pebbles	20	240
Light-brown clayey sand, particles of black iron carbonate and coal, shell fragments, water very salty	20	260
Light-brown clayey sand, black iron carbonate and coal	20	280
Light-gray clayey sand, shell fragments. At 320 feet a ledge of black iron carbonate and coal was struck	120	400
Light-gray coarse clayey sand, shell fragments, small vein of gray shale	80	480
Gray shale, variegated pebbles, quartz, calcite, gravel and coarse sand, strong salt water	37	517
Light-gray clayey sand, shell fragments, black iron carbonate and coal	19	536
Light-gray fine sand, shell fragments, coal and mica	34	570
Variegated coarse sand, gravel, shell abundant, coal, quartz, disintegrated flint rock, mica	30	600
Fish vertebræ, calcareous concretions, petrified wood, variegated coarse gravel, quartz, disintegrated flint rock, shell abundant	20	620
Variegated coarse gravel, shell fragments, coal, quartz, lignitized wood, disintegrated flint rock, flora remains, fish vertebræ, gray clay	29	649

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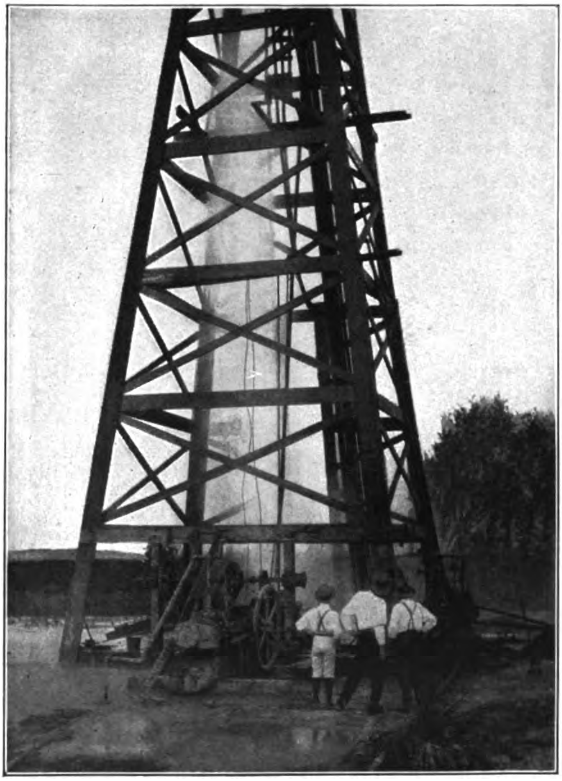
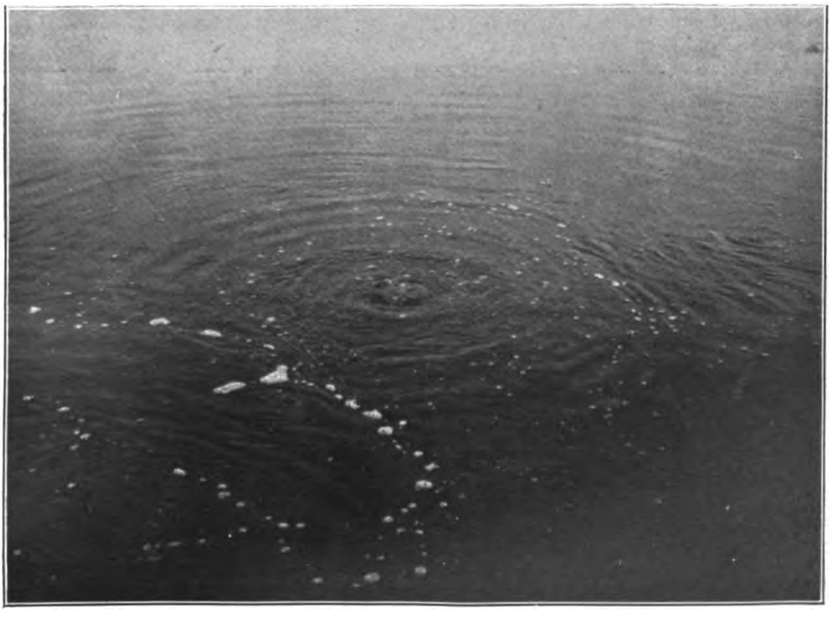
[a] Letter of August 5, 1909.



A. LIRETTE GAS WELL, TERREBONNE PARISH.

Photograph furnished by I. N. Knapp.



B. GAS ESCAPEMENT IN LAKE FELICITY, TERREBONNE PARISH.

Photograph furnished by I. N. Knapp.

Log of "Magenta" well, Montegut—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Variegated coarse gravel, shell fragments, coal, calcareous concretions, disintegrated flint rock, quartz, gray clay, gas showing	21	670
Lignitized wood, gray clay, some gravel	14	684
Variegated coarse gravel, shell fragments, disintegrated flint rock, quartz, gray clay, soft flora remains, strong gas showing	16	700
Fine gray sand and mica, light-gray clay, gas and oil showing. At 742 feet a ledge of light-gray shale was struck, white quartz, variegated gravel, pebbles, lignite, manganese, black iron carbonate, strong salt water	100	800
Light-gray sand, gas showing	45	845
Light-gray sand, streak of blue clay, gas showing	20	865
Light-gray clay, white sand, disintegrated flint rock, small pebbles, variegated gravel, shell abundant, salt water, oil showing	23	888
Light-gray sand, gravel, shell fragments, wood, considerable gray clay	17	905
Light-brown clay, fine gray sand, calcareous concretions	43	948
Light-gray clayey sand, shell fragments, mica, disintegrated flint rock, flora remains	32	980
Light-gray clayey sand, shell fragments, flora remains	30	1,010
Light-gray sand, calcareous concretions, oil showings	46	1,056
Light-gray sand, shell fragments, flora remains, oil showing. Water collected on ditch at 1,056 feet with oil showing, odor of petroleum and sulphureted hydrogen	28	1,084
Gray clayey coarse sand, flora remains, shell fragments, calcareous concretions, oil showing, odor of decomposed fish, water very salty	24	1,108
Light-gray fine sand, clay, shell fragments, oil showing	16	1,124
Light-gray fine sand, shell fragments, oil showing	16	1,140
Light-gray sand, clay, oil showing	20	1,160
Gray sand, clay, shell fragments, oil showing at 1,170 feet	12	1,172
Variegated gravel, some sand, disintegrated flint rock, shell fragments, quartz	2	1,174
Variegated gravel, dolomitic rock, shell fragments, fish vertebræ. The bailer brought up light-gray sand, variegated coarse gravel, disintegrated flint rock, sand-rock fragments, oil showing, water extremely salty. (See analysis below)	3	1,177
No sample	3	1,180
Medium fine sand, quartz, calcareous concretions. At 1,181 feet a ledge of coarse gravel and dolomitic rock was encountered, also light-gray oil sand with black pebbles and pyrites. The sand contained a considerable amount of dark amber, heavy mineral oil and paraffin	10	1,190
Light-gray fine sand, pebbles, shell fragments, dolomitic rock, gravel, oil showing	10	1,200
Light-gray fine sand, dolomitic rock, mica, gravel, disintegrated flint rock	40	1,240
Light-gray sand, particles of rock, strong salt water	20	1,260
Light-gray clayey sand, calcareous concretions, very salty water	20	1,280
Light-gray clayey sand, calcareous concretions. At 1,290 feet a streak of dark clay was struck, odor strong of petroleum, considerable oil showing	20	1,300
Light-gray clayey sand, calcareous concretions. At 1,328 feet the drill brought up tenacious blue shale and large variegated pebbles. Oil showing good, water strong, salty	28	1,328
Gray clay abundant, chips of flint, calcite, gravel and iron pyrites in good quantity, pure mica, slight oil showing. At 1,388–1,398 feet a bed of shells was struck (cephalopod and pecten) containing flakes of anthracite coal	122	1,450
Gray clay abundant, variegated quartz, flakes of anthracite coal, pyrites, shell fragments, animal vertebræ	10	1,460
Red clay abundant, variegated quartz and gravel, anthracite coal and pyrites, magnesian limestone shells	3	1,463
Coarse gray sand and quartz, gravel, concretions, shells, slight oil showing, anthracite coal, and mica	4	1,467
Red clay abundant, variegated quartz, sand, fish vertebræ, shell fragments, carbonate of iron, pyrites in good quantity, slight oil showing. At 1,519 feet a ledge of Devonian flora remains. Shells *Tropidoleptus carinatus*	78	1,545
Red clay abundant, shell and wood fragments, pebbles, concretions, and fish vertebræ, slight oil showing. Samples from 1,467–1,581 feet contained pebbles, quartz, sand, shell fragments, and anthracite ferruginous carbon. The shells are from the Devonian era. Pieces of Genesee slate	36	1,581
Gray clay, gray sand, shells and quartz, oil showing	45	1,626
Gray clay and sand. Devonian shells abundant, wood remains, fish vertebræ, oil showing, water salty. From 1,600–1,670 feet flakes of black slate were encountered equal to those found in coal mines	66	1,692
Dark-gray shale, Devonian shells, fish scales, pyrites, quicksand, red iron oxide, gravel	18	1,710
Intermediate sample: Considerable oil showing, dark-brown clay, fine micaceous oil sand, pyrites abundant, large gravel, Devonian shells, quicksand, gas showing.		
Light-gray shale with oil showing, Devonian shells, fish scales, pyrites, red iron oxide, gravel	40	1,750
Intermediate sample: Dark-gray clay, gravel, Devonian shells, flora remains, red iron oxide, quicksand.		
Gray shale abundant, Devonian shells, pyrites, flora remains, quicksand, iron concretions, mica	10	1,760
Gray clay, slight oil showing, Devonian shells, mica, flora remains, quicksand	7	1,767
Gray clay abundant, slight oil showing, fish vertebræ, pyrites, white quartz, concretions, quicksand	1	1,768
Carbonate of iron abundant, fine sand, quartz, flint rock, fish vertebræ and fish teeth, Devonian shells, shell fragments, gray clay	2	1,770
Carbonate of iron, fine sand and quartz, fish vertebræ, Devonian shells, bluish-gray clay	25	1,795
Carbonate of iron, gray clay, Devonian shells, very fine quicksand, slight oil showing	35	1,830
Carbonate of iron, iron oxide, gray clay, Devonian shells, fine oil sand	15	1,845
Carbonate of iron, iron oxide, gray clay, Devonian shells, fine oil sand, oil extracted in paying quantities	12	1,857

Log of "Magenta" well, Montegut—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Quicksand, iron carbonate, shells, concretions, oil showing, bluish-gray clay	8	1,865
Yellowish-gray clay, good oil showing, fine oil sand	17	1,882
Intermediate sample (1,880 feet): Coarse oil sand, flora remains abundant, shell fragments.		
Quicksand, carbonate and iron oxide, splendid oil showing	25	1,907
Carbonate of iron, quicksand, very good oil showings	33	1,940
Fine white micaceous sand, quartz, shell fragments, good oil showing	15	1,955
Gray clay, gray sand, iron carbonate, lignite, shell fragments	11	1,966
Ferruginous clay, gray speckled micaceous sand, good oil showing. From 1,965-1,985 feet gray oil sand	34	2,000
Ferruginous clay, gray micaceous sand, oil showing	10	2,010

Oil horizons in the "Magenta" well.

	Feet.		Feet.
Slight oil indication	60	Considerable oil indication	1,260-1,300
Do	700	Good oil indication	1,328-1,450
Good oil indication	888	Slight oil indication	1,545
Slight oil indication	1,056	Do	1,626-1,692
Do	1,108	Medium oil indication	1,710-1,750
Do	1,124	Slight oil indication	1,768
Do	1,160	Do	1,830
Good oil indication	1,190	Good oil indication	1,845-1,955
Slight oil indication	1,200		

Sample of water from the "Magenta" well, depth 1,174 to 1,177 feet: Specific gravity, 1.022; reaction, neutral; taste, extremely salty; color, clear white; small sediment. Chemical composition: Total solids in 1 United States gallon, 4,381.12 grains; sodium chloride, strong; calcium chloride, strong; aluminum chloride, strong; magnesium chloride, strong; barium chloride, small; potassium chloride, small; lithium chloride, small; sodium iodide, small; calcium phosphate, small; boracic acid, small; iron bicarbonate, small; sulphuric acid, none.

To this report on the "Magenta" well should be added Professor Thiele's analysis of and remarks on the gas from the Lower Terrebonne Refining and Manufacturing Company's "Phyllis" well, also at Montegut, as follows:

Analysis of gas from "Phyllis" well, Montegut.

	Per cent.
Methane	89.099
Olefiant gas	4.450
Carbon monoxide	.100
Carbon dioxide	1.000
Hydrogen	1.750
Nitrogen	3.500
Oxygen	.100
Sulphureted hydrogen	.001

The above analysis shows the gas found at Montegut, La., and vicinity, to be derived from subterranean deposits of mineral oil. Its composition indicates that it is generated from deposits of light-gravity oil, practically free from sulphur and sulphur compounds.

The olefiant gas contained in the Montegut natural gas is ethylene and its homologues, while acetylides, such as are found in the East Texas oils, are found in it to a certain extent. The olefiant gases are also found in the water being brought to the surface by the drills, but on account of their volatile character they evaporate almost immediately on exposure to the air. The large amount of methane found is explained by the fact that the gas is a final product of the slow but constantly decomposing oil deposit underlying. If a sufficient quantity could be secured, the gas would prove commercially valuable for heating and mechanical purposes. The total composition of the gas proves that Montegut is oil-bearing territory. In comparison with other gases it resembles very closely the natural gas of Leechburg, Pa.

LIRETTE WELL.

A concise and interesting history of the drilling operations on the Lirette farm, in sec. 51, T. 19 S., R. 19 E., is given in the Oil Investors' Journal for September 6, 1908, page 18. The well was drilled in 1904 to a depth of 1,080 feet without satisfactory results, and operations were suspended. Pickard and Heywood Brothers commenced deepening the hole in August, 1908. Pickard set his 4-inch casing at 1,371 feet and then went down with a 2½-inch drill. During a few hours' halt at 1,710 feet, August 19, the well commenced to blow dry gas; then water coming in below the 4-inch pipe caused the well to blow salt water and some sand. The 6-inch and 8-inch casings were abraded and loosened, and a crater 15 feet in diameter was formed by August 31. The well was ignited and, like the Caddo wild wells, presented a marvelously spectacular appearance. The illustration (Pl. XXII, *A*), from a photograph furnished by Mr. Knapp, shows the well before the derrick was cut down and the gas ignited. The daily production of gas is estimated at 5,000,000 to 7,500,000 cubic feet. The record of the well below 1,080 feet, as furnished by Capt. M. H. Pickard, is as follows:

Partial record of Lirette well.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sand	55	1,135	Gumbo with shells in it	22	1,457
Gumbo	7	1,142	Shale	43	1,500
Sand (gas)	148	1,290	Gumbo	25	1,525
Gumbo	30	1,320	Hard shale (gas)	75	1,600
Sand	2	1,322	Loose shale and shells (gas)	25	1,625
Gumbo	23	1,345	Hard shale (gas)	25	1,650
Sand	5	1,350	Hard shale and shells (gas)	60	1,710
Gumbo (set 4-inch pipe at 1,371 feet)	68	1,418	Soft rock (gas)	2	1,712
Sand	7	1,425	Shale (gas)	14	1,726

Lost mud in soft places between 1,525 feet and 1,710 feet.

Stopped drilling on August 18, 1908, and the well blew out on August 19.

On his manuscript section of the well Pickard adds the following note:

> Slush pump broke down August 18. Well blew out August 19. First twenty-four hours well reported dry, then water broke in. Well blew ninety-nine days without any apparent weakening, then shut off by a cave-in from the surface. Sand thrown out equals 3 to 4 acres 1 foot deep.

KNAPP WELLS.

As already stated, I. N. Knapp has put down five wells in various parts of Terrebonne Parish. Their locations are shown in figure 21. While drilling these wells Mr. Knapp sent to the writer a large number of fossils from various horizons in wells 1, 2, and 3. Some of these were accompanied with statements regarding the character of material in which the fossils were found. Such statements, together with the lists of fossils from each horizon, are herewith given in full.

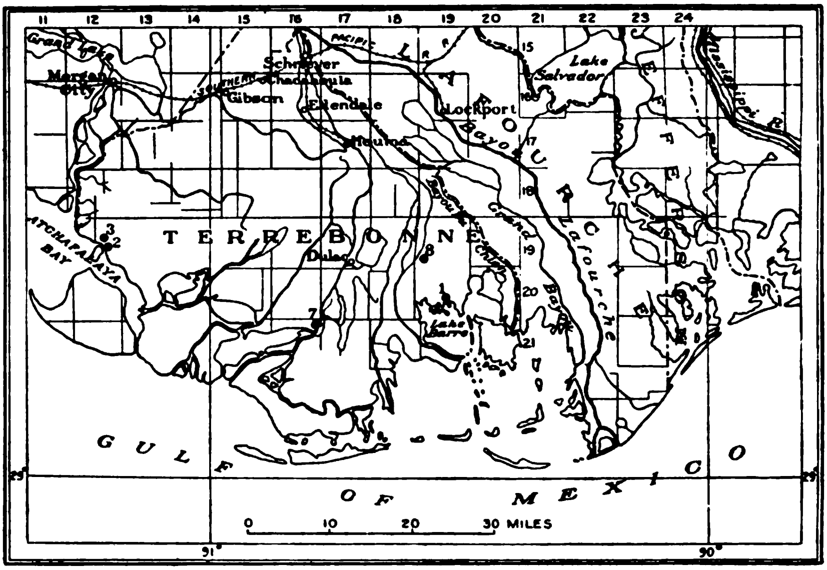


FIGURE 20.—Map of Terrebonne Parish, showing location of Knapp wells.

Knapp well No. 1, southeast part of T. 20 S., R. 19 E., on Lake Tambour, at head of Oyster Bayou.

Drilled December, 1906, to February, 1907. Datum, 1 foot above mean low water.

	Feet.
Marsh grass and roots	4
Mud	26
Bed of shells	30
Blue clay	75
Blue clay and lime concretions	100
Gas, no odor; would not tarnish silver coin; burned all night from 2-inch pipe, making flame 6 feet high	140
Blue clay	170
Sand and shells	175
Brown, woody material	180
Sandy clay	270
Soft sandy clay	320
Hard shale or clay	360
Softer	378

	Feet.
Tough clay or gumbo	390
Drilling freely	430
Drilling harder with shells showing in overflow; some crumbly sandstone found on coupling	640
Samples of blue clay got from bailer	695–700
Drilled tough, with pellets of clay in overflow	700–750
Showing of shells	750–755
Coarse reddish sand in overflow	830
Sand with shells	865
Coarse, sharp sand	880–895
Very sticky clay or gumbo	910–925
Alternating streaks of sticky and sandy clay	925
Light, coarse shales	1,130
Free-drilling sandy clay or shale	1,180–1,200
Hard, light rock	1,372–1,380
Greenish shales	1,405
Broken shells; coarse gravel on coupling	1,450–1,455
Pulled out to sharpen bit and found gravel on bit and joints below 1,400 feet	1,486
Pulled back and found gritty limestone on coupling	1,505
Bailed, no pressure	1,550
Tough clay shales and gumbo, requiring frequent spudding to free the bit. Shells: *Arca transversa*, *Cerithium*, *Corbula contracta*, *Dosinia*, *Leda acuta*, *Lucina acuminata*, *Nassa acuta*, *Olivella mutica* ?, *Ostrea virginica*, *Pecten gibbus* var. *irradians*, *Terebra dislocata*, *Turritella variegata*. At 1,620 feet blue clay came in. It was supposed that the 6-inch casing was set in clay and possibly it was in a thin streak. Had the 6-inch casing held at 1,620 feet it is probable that we would have gotten much deeper	1,600–1,700
Bed of shale, showing as mud in overflow. At 1,730 feet, fossils, sent to United States Geological Survey	1,700–1,880
Cuttings of shale showing in overflow	1,900
Hard, ground like rock	1,944–1,950
Rock	1,961–1,971
Lignite, shark's tooth	2,000
Fossils obtained from indurated light-gray clay, almost shale: *Arca campechensis*, *A. transversa*, *Cardium robustum*, *Chione latilirata*, *Corbula contracta*, *Lucina crenella*, *Murex spinicostata*, *Nassa acuta*, *Oliva litterata*, *Pecten gibbus* var. *dislocatus*, *Rangia cuneata*, *Terebra dislocata*, *Tritonidea cancellaria*, *Vermetus*	2,001–2,150
Black peat, abundant	2,233–2,335
Shells: *Anachis*, *Arca campechensis*, *A. transversa*, *Cardium robustum*, *Chione cancellata*, *Chione latilirata*, *Corbula contracta*, *Eulima*, *Lucina crenella*, *L. amiana*, *Nassa acuta*, *Oliva litterata*, *Ostrea*, *Pecten gibbus* var. *irradians* and *dislocatus*, *Scala multistriata*, *Tellina alternata*, *Tritonidea cancellaria*, *Turritella variegata* ?	2,250–2,450
Bottom of well	2,471

Twelve-inch casing set at 80 feet; 9-inch casing set at 620 feet; 6-inch casing set at 1,620 feet; 4-inch casing set at 2,471 feet.

Knapp well No. 2, 14 miles southeast of Belle Isle, in sec. 22, T. 19 S., R. 12 E.[a]

Drilled March 28 to August 5, 1907.

Besides the large number of organic remains found between 1,000 and 1,900 feet, there is little of special interest in this well. Its depth is 2,463 feet. From 1,900 feet to the bottom shells are said to be very scarce. From 1,800 to 2,000 feet "black, greasy shales, sand, salt water, and gas" are recorded. Between 2,030 and 2,087 feet a sufficiently indurated layer is encountered to be recorded as "rotten limestone." Finally, "Lower 112 feet, fine-grained sandy shale; fifteen days required to drill this distance." The fossils from this well and their range in depth will be found in the list given below.

Datum, 1 foot above tide.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil with roots	4	4
Dark-brown soil and roots shading into gray sticky mud and shells	10	14
Light-gray mud or clay	28	42
Clean sharp sand	12	54
Grayish mud or clay with bits of rotten wood or peaty material	83	137
Sand	50	187
Clay with woody materials; some gas, 192 feet	33	220
Sand with broken shells	16	236
Clay with woody and boggy materials	114	350
Wood, bark and fiber	5	355
Stiff clay, wood and woody fiber	125	480
Wood	3	483
Stiff clay	7	490
Sand with bits of shells and crinoid stems. This sand would take clean water faster than the pumps could throw it, so had to mix mud to pump in and puddle walls of well	106	596
From 596 to 1,025 feet record indefinite, from mud used in drilling. Alternate streaks of clay, shale, gumbo, sand, shells, and woody materials occurred at 989 feet, end of 9-inch pipe in a stump or log	399	995
Shale or gumbo with lignite and wood fiber requiring spudding	64	1,059
Sand	5	1,064
Gumbo with wood fiber	26	1,090
Streaks of differently colored shale with woody fiber	80	1,170
Abundance of broken shells	5	1,175
Streaks of different colored shale with bits of lignite and bits of woody fiber. Streaks of shells	155	1,330
Sandy materials	40	1,370
Shales with streaks of shells	60	1,430
Rock	2	1,430
Greenish-gray shales	16	1,448
Rock	1	1,449
Sticky shales	21	1,470
Brick-red particles and sandy materials	5	1,475
Sticky shales	13	1,488
Rock	12	1,500
Shale	16	1,516
Rock	9	1,525
Shale	25	1,550
Shells, sand, and lignite	10	1,560
Sticky shales in light and dark gray streaks, requiring frequent spudding	70	1,630
Shale and lignite	5	1,635
Streaks of gray and greenish-gray shales or gumbo, very sticky, requiring frequent spudding. Occasional streaks of shells and woody fiber	85	1,720
Hard, like rock, probably limestone	28	1,748
Shale, abundance of coarse gravel, origin unknown; record from 1,748 to 2,300 feet indistinct and not accurate on account of thick mud used in drilling to keep back sand. Between 1,850 and 1,870 feet, 6-inch pipe perforated, giving gas, salt water, and sand; at 1,884 feet, gas with iridescence like oil	136	1,884
Harder, and decided change in fossils. Apparently gravel and shells cemented with clay	9	1,893
Shale with shells, sand, and gravel, growing whiter by depth	27	1,920
Sand, showing gas and iridescent colors; 6-inch casing set at 1,942 feet, did not hold; sand and salt water broke through underneath	20	1,940
Stiff dark shale or clay	50	1,990
Rock, fine cuttings and sand in overflow	40	2,030
Rotten rock, like limestone	57	2,087
Standard, finely broken shells in overflow	11	2,098
Hard like rock	28	2,126
Shales and sandy shales; variable hardness, no shells	74	2,200
Fragments of black shale which were lighter on drying	16	2,216
Streaks of various colored shales. Packer set at 2,242 feet	24	2,240
Rock, hard sandy materials. Test between 2,269-2,289 feet showed no gas, oil, or water	49	2,289
Shale, appearing silvery at overflow between 2,295 and 2,300 feet	20	2,309
Sand, test between 2,332 and 2,352 feet showed no gas, oil, or water	42	2,351
Sandy shales, variable in color and hardness	112	2,463

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[a] This well may be located on United States Coast and Geodetic Survey sheet No. 129 by following up the left bank of Alligator Bayou about three-fourths of a mile from its mouth at Alligator Point.

Knapp well No. 3, sec. 15, T. 19 S., R. 12 E.[a]

Drilled August 3 to November 9, 1907.

At 1,032 to 1,037 feet, with a streak of shells, I got sand and an artesian water. I did not taste salt or sulphur in the flow. The temperature of the overflow was 78° F. I think the flow was not more than 50 nor less than 10 gallons per minute, and there was a little bubbling of gas with it.

There is a considerable degree of conformity between my No. 2 and No. 3 wells drilled about a mile apart. The strata that I could clearly recognize were from 40 to 160 feet higher in No. 3 than in No. 2.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and roots	1	1
Dark gray clay and roots	3	4
Gray clay, growing lighter in color	29	23
Streak of shells	1	24
Grayish clay	21	45
Soft grayish clay	9	54
Streak of shells	1	55
Gray clay with woody fiber and shells	63	118
Light-colored crumbling material	4	122
Grayish clay	16	138
Clean sharp sand with specks of shells	69	207
Yellow clay	1	208
Sand with bits of shells, growing coarser toward bottom	22	230
Clay or gumbo with streaks of shells; hard streak and spudding at 250 feet	30	260
Pieces of green shale appeared at 260 feet. Various colored shales or clay with some shells and much wood fiber	28	288
Various colored clays or shells with wood and woody fiber and a few shells and possibly streaks of sand	215	503
Mostly clean, sharp sand with a few shells and possibly streaks of clay. Exact bottom of sand indefinite. At 502 feet end of 12-inch casing. Crinoid fragments in the sand	133	636
Shale or clay	36	672
Hard, like rock	3	675
Clay or shale, variable in color and hardness	136	811
Hard streak	1	812
Clay or shale	11	823
Hard clay or shale	5	828
Probably clay, with woody fiber	54	882
Soft material, possibly sand	20	902
Clay or shale, variable in character. Spudding along about 1,000 feet; at 1,018 feet end of 9-inch casing; bit pulled back from 1,021 feet showed black sticky clay	130	1,032
Great abundance of shells	3	1,035
Sand and artesian water, possibly some gas	4	1,039
Dark-brown to black shales	33	1,072
Green to bluish-green shales, requiring frequent spudding	98	1,170
Hard shales, cutting freely	122	1,292
Hard shell	1	1,293
Hard shale	13	1,306
Hard shell	1	1,307
Shales of variable color and hardness; few shells at 1,436 feet	109	1,416
Hard shell	1	1,417
Shale	9	1,426
Hard shell	1	1,427
Sticky clay or shale	35	1,462
Abundance of broken oyster shells	10	1,472
Clay and shales, variable	49	1,521
Gritty rock, wearing bit badly	5	1,526
Clays and shales, sticky, variable hardness	49	1,575
Rocks	1	1,576
Clay or shale, sticky, requiring spudding	44	1,620
Rock	2	1,622
Clay and shale with bits of pyrite and sandstone	70	1,692
Sand with small oil showing	12	1,704
Hard light-blue shale with slight showing of oil	56	1,760
Soft clay or shales	12	1,772
Clay or shale	28	1,800
Hard shell with slight show of oil	1	1,801
Clay or shale; 6-inch casing set at 1,832 feet	36	1,836
Sand	2	1,838
Clay or shale	19	1,857
Salt-water sand	89	1,946
Hard materials	4	1,950
Hard yellowish rock, probably some kind of limestone with flint	38	1,988
Soft material, giving overflow a yellowish color. Short hollow pieces in overflow	4	1,992
Hard drilling, supposed to be gypsum	29	2,021

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[a] See United States Coast and Geodetic Survey sheet No. 199, left bank, mouth of Blue Hammock Bayou.

Knapp well No. 7, sec. 1, T. 21 S., R. 16 E., on the Grand Caillou.

Drilled summer 1909, completed July 10, 1909.

No traces of oil or gas shown in well, though gas escapements at the surface near by are abundant. Measurements are from rotary jaws, 7 feet above the surface and 8½ feet above mean low tide.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface	7	7
Surface mud with wood and bits of shells	63	70
Grayish clay	98	168
Sand with gas and water; water brackish but used in boilers	16	184
Clay	81	265
Sand	28	293
Blue clay; abundance of wood fiber; some shells	197	490
Sand	45	535
Grayish clay or shale	130	665
Streaks of reddish and chocolate shales in gray clay	60	725
Alternate layers of sand and clay	85	810
Sand, fine on top, growing coarse at bottom	75	885
Streaks of gray and blue shales with soft white stuff; abundance of shells; little gas.	45	930
Soft gray and blue shales with wood and shells	115	1,045
Streaks of shell and stuff like gypsum	22	1,067
Alternate hard and soft streaks of gray and blue clays	68	1,135
Grayish clay	82	1,217
Sand	95	1,312
Shale, shells, and flints	83	1,385
Blue clay	10	1,395
Shale, shells, and layers of blue clay	156	1,551
Fine sand	46	1,597
Gumbo and shells	24	1,621
Clear sand (no shells)	109	1,730
Greenish shale and shells	4	1,734
Sand	4	1,738
Gumbo; mud on bit showed pyrites	43	1,795
Shale; no shells	78	1,873
Light-colored, fine-grained shale at 1887-1892 feet. Hard, like rock	29	1,902
Abundance of broken shells	3	1,905
Woody fiber in shale	....	1,920
Dark sticky shale	82	2,002
Clay and shales	114	2,116
Wood and woody fiber abundant	2	2,118
Clay and shales	64	2,182
Shales, with shells	7	2,189
Hard shells or rock	3	2,192
Gray shales with hard streaks and lignitic wood	108	2.300
Sand and lost mud	16	2,316
Shale and wood	15	2,331
Sand and lost mud	18	2,349
Shale and lignitic wood	16	2,365
Sand	61	2,426
Dark shale at top and light at bottom; hard streaks	38	2,464
Sand and gravel, lost mud, crinoid stems	109	2,573
Light-gray shale	67	2,640
Sand	10	2,650
Light-gray shale	35	2,685
Sand	15	2,700
Alternate sand and clays	137	2,837
Alternate streaks of gray and blue clay	125	2,962
Fine sand	5	2,967
Shale and shell; fresh-water clean shells	33	3,000
Fine sand	18	3,018

Knapp well No. 8, lot 15, sec. 33, T. 19 S., R. 19 E.

Drilled July 10–September 15, 1909.

This well is about 2,000 feet from the Lirette well. It was ruined by a blow-out from gas pressure below 1,600 feet.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface materials	5	5
Black sandy loam	5	10
Fine salt and pepper sand; gas	170	180
No record	60	240
Coarse water sand	21	261
Alternate layers, gray clay and water sand; gas	13	274
Sand and gravel	95	369
Light-gray clay and wood fiber alternating with coarse sand and flint	30	399
Fine sand	118	517
Light-gray clay, shaly in character; shells; no gas; set 12-inch casing at 570 feet	85	602
Sand	31	633
Shale and sand; shells	52	685
Reddish to coarse, gray sand	125	810
Gravel with flint	18	828
Gray and red clay with gas	22	850
Sand	91	941
Sand and gravel mixed with red, blue, and gray clay; large amounts of flint	108	1,049
Soft gray shale	22	1,071
Gravel with flint; black crystals	20	1,091
Soft gray shale	10	1,101
Gravel	7	1,108
Red and gray clays	13	1,121
Very soft light-gray clays; gas	47	1,168
Stiff light-gray clay	77	1,245
Stiff gray clay and shells	20	1,265
Light-gray shale, variable, sometimes sticky, sometimes balling up	165	1,430
Shells in shale	20	1,450
Gray shale of variable hardness. End of 6-inch casing at 1,495 feet	150	1,600
Sand and shells	17	1,617
Gray and green shales, hard. Bottom of 5⅝-inch hole; gas blew well out	28	1,645

SHELLS FROM TERREBONNE PARISH AND THEIR BEARING ON STRATIGRAPHY AND OCCURRENCE OF OIL AND GAS.

Below is given in alphabetic order a list of the molluscan species identified by Doctor Maury from the Knapp wells of Terrebonne Parish and of those that have been identified with certainty from Point au Fer, in the same parish, as well as those from the Gymnasium well at New Orleans. The object in presenting this list is to show the basis for the statement that none of these wells have penetrated beds that can be regarded as older than Pleistocene. Some specific remarks by Doctor Maury seem pertinent here:

> The only possible suggestions of affinities with a Tertiary fauna were as follows: In well No. 2 at a depth of 1,800 feet a *Pleurotoma* occurred which is somewhat like *P. quadricentennialis* Harris from the upper Miocene of the Galveston well and is possibly a varietal form, but more likely a different species. In No. 1 at 2,000 to 2,150 feet two specimens of *Chione latilirata* Conrad were found which showed the irregular sulcations which at first sight recall the Miocene type of the species. But although in the Recent fauna the form with regular sulcations is more characteristic, still the irregular, ancestral, Miocene type continues to develop and is often found living. And at the same level at which the *Chione* was found in the well there were 15 other species, all of which are Recent. In No. 3 a *Mangilia* like the recent *limonitella* Dall but more cancellate and probably a new species was found at a depth of from 1,500 to 1,525 feet.

It might seem that the presence of several new species would weaken the relationship of the well faunas to the Recent, but the Mollusca of the Gulf are not thoroughly well known and new species are being found by conchologists at the present time in Texas and west Florida.

Considering the fauna of the three wells as a whole, the conclusion is inevitable that the Pleistocene strata have in this part of Terrebonne Parish a thickness of at least 2,443 feet.

It is certainly interesting to note, in studying the shells from the Gymnasium well at New Orleans from a depth of only 1,200 feet, that they comprise more new species, or species not now known to be living in the Gulf waters, than are obtained from the much deeper wells in Terrebonne Parish. A complete illustrated description of the Gulf coast Pleistocene and Recent molluscan fauna is now in preparation. Knapp wells Nos. 1, 2, and 3 are certainly not located on prominent local uplifts, such for example as that of the Jennings oil field, where the Tertiary *Rangia johnsoni* approaches in places within 1,000 feet of the surface.

Alphabetic list of species, mainly molluscan, found in and about Terrebonne Parish, with range in depth in wells and geologic range of each species.

[Figures indicate depth in feet.]

- Abra æqualis.
  - Knapp No. 2, 1,050-1,542.
  - Point au Fer.
  - Miocene to Recent.
- Adeorbis supranitidus.
  - Knapp No. 2, 1,519-1,632.
  - Oligocene to Recent.
- Anachis avara.
  - Point au Fer.
  - Pleistocene and Recent.
- Anachis obesa.
  - Knapp No. 2, 1,050-1,800.
  - Knapp No. 3, 1,150-1,440.
  - Point au Fer.
  - Pliocene to Recent.
- Anomia simplex.
  - Knapp No. 3, 1,330-1,470.
  - Gymnasium, 1,200.
  - Oligocene to Recent.
- Arca campechensis.
  - Knapp No. 1, 2,000-2,450.
  - Knapp No. 2, 1,800.
  - Knapp No. 3, 300-900.
  - Gymnasium, 1,200.
  - Point au Fer.
  - Miocene to Recent.
- Arca ponderosa.
  - Knapp No. 2, 1,519-1,842.
  - Knapp No. 3, 670-1,700.
- Arca ponderosa—Continued.
  - Point au Fer.
  - Pliocene to Recent.
- Arca transversa.
  - Knapp No. 1, 1,600-2,450.
  - Knapp No. 2, 1,050-1,842.
  - Knapp No. 3, 570-2,029.
  - Gymnasium, 1,200.
  - Point au Fer, 0.
  - Pliocene to Recent.
- Astyris lunata.
  - Knapp No. 2, 1,050-1,790.
  - Knapp No. 3, 258-1,375.
  - Pliocene to Recent.
- Barnea costata.
  - Knapp No. 2, 1,434-1,542.
  - Knapp No. 3, 510-1,375.
  - Point au Fer, 0.
  - Miocene to Recent.
- Callocardia texasiana.
  - Knapp No. 2, 1,542-1,632.
  - Knapp No. 3, 570-800.
  - Point au Fer.
  - Recent.
- Cardium robustum.
  - Knapp No. 1, 2,000-2,450.
  - Knapp No. 2, 1,190-1,842.
  - Knapp No. 3, 1,200-1,300.
  - Miocene to Recent.

Alphabetic list of species, mainly molluscan, found in and about Terrebonne Parish, with range in depth in wells and geologic range of each species—Continued.

Cassis inflata.
  Knapp No. 1.
  Knapp No. 2, 1,791-1,842.
  Point au Fer, 0.
  Pleistocene and Recent.
Chione cancellata.
  Knapp No. 1, 2,250-2,450.
  Knapp No. 2, 1,731-1,739.
  Knapp No. 3, 570-1,525.
  Gymnasium, 1,200.
  Miocene to Recent.
Chione grus.
  Knapp No. 2, 1,434 to 1,842.
  Gymnasium, 1,200.
  Point au Fer.
  Miocene to Recent.
Chione intrapurpurea.
  Knapp No. 2, 1,050-1,190.
  Knapp No. 3, 700-1,043.
  Pleistocene and Recent.
Chione latilirata.
  Knapp No. 1, 2,000-2,443.
  Miocene to Recent.
Congeria leucopheata.
  Knapp No. 2, 1,542-1,570.
  Knapp No. 3, 0-2,029.
  Point au Fer, 0.
  Pleistocene and Recent.
Corbula contracta.
  Knapp No. 1, 1,600-2,443.
  Knapp No. 2, 1,190-1,842.
  Knapp No. 3, 570-1,739.
  Miocene to Recent.
Crassatellites lunulata.
  Knapp No. 2, 1,190-1,800.
  Knapp No. 3, 700-1,842.
  Gymnasium, 1,200.
  Pliocene to Recent.
Crepidula plana.
  Gymnasium, 1,200.
  Oligocene to Recent.
Cylichnella bidentata.
  Knapp No. 2, 1,519-1,542.
  Miocene to Recent.
Cyrene floridana.
  Point au Fer, 0.
  Pleistocene and Recent.
Dentalium texasianum.
  Knapp No. 2.
  Point au Fer, 0.
  Pleistocene and Recent.
Donax tumida.
  Gymnasium, 1,200.
  Point au Fer, 0.
  Pleistocene and Recent.
Dosina discus.
  Knapp No. 2, 1,519-1,542.
  Knapp No. 3, 570-1,712.
  Pliocene to Recent.
Drillia quadricentennialis var.
  Knapp No. 2, 1,800.
  Miocene to (?).
Fasciolaria gigantea.
  Point au Fer, 0.
  Pliocene to Recent.
Fulgur canaliculatum.
  Point au Fer, 0.
  Pleistocene and Recent.
Fulgur perversum.
  Point au Fer, 0.
  Miocene to Recent.
Labiosa canaliculata.
  Knapp No. 2, 1,502-1,632.
  Knapp No. 3, 1,330-1,375.
  Point au Fer, 0.
  Miocene to Recent.
Leda acuta.
  Knapp No. 1, 1,600-1,700.
  Knapp No. 2, 1,050-1,632.
  Knapp No. 3, 570-1,300.
  Gymnasium, 1,200.
  Point au Fer, 0.
  Oligocene to Recent.
Littorina irrorata.
  Point au Fer, 0.
  Miocene to Recent.
Lucina amiana.
  Knapp No. 1, 1,600-2,450.
  Knapp No. 2, 1,050-1,842.
  Knapp No. 3, 800-1,839.
  Gymnasium, 1,200.
  Pleistocene and Recent.
Lucina crenella-multilineata.
  Knapp No. 1, 2,000-2,450.
  Knapp No. 2, 1,050-1,790.
  Knapp No. 3, 1,150-1,525.
  Gymnasium, 1,200.
  Pliocene to Recent.
Mangilia cerina.
  Knapp No. 1.
  Knapp No. 2, 1,190-1,420.
  Knapp No. 3, 1,500-1,525.
  Pleistocene and Recent.

Alphabetic list of species, mainly molluscan, found in and about Terrebonne Parish, with range in depth in wells and geologic range of each species—Continued.

Mangilia limonitella.
    Knapp No. 3, 1,150–1,200.
    Pleistocene and Recent.

Melampus flavus.
    Point au Fer, 0.
    Recent.

Melampus lineatus.
    Point au Fer, 0.
    Recent.

Mulinea var. corbuloides.
    Point au Fer, 0.
    Pleistocene.

Mulinea lateralis.
    Knapp No. 2, 1,050–1,842.
    Knapp No. 3, 700–2,029.
    Gymnasium, 1,200.
    Point au Fer, 0.
    Miocene to Recent.

Murex spinicostata.
    Knapp No. 1, 2,000–2,150.
    Knapp No. 3, 790–800.
    Point au Fer, 0.
    Pleistocene and Recent.

Mytilus hamatus.
    Knapp No. 2, 1,434–1,726.
    Knapp No. 3, 570–700.
    Point au Fer, 0.
    Pliocene to Recent.

Nassa acuta.
    Knapp No. 1, 1,600–2,443.
    Knapp No. 2, 1,050–1,842.
    Knapp No. 3, 58–1,839.
    Gymnasium, 1,200.
    Point au Fer, 0.
    Miocene to Recent.

Natica pusilla.
    Knapp No. 3, 1,150–1,525.
    Gymnasium, 1,200.
    Pleistocene and Recent.

Neverita duplicata.
    Knapp No. 2, 1,190–1,790.
    Knapp No. 3, 1,150–1,839.
    Gymnasium, 1,200.
    Point au Fer, 0.
    Miocene to Recent.

Niso interrupta var. æglees.
    Knapp No. 3, 1,150–1,200.
    Pleistocene and Recent.

Oliva litterata.
    Knapp No. 1, 2,000–2,150; 2,250–2,450.
    Knapp No. 2, 1,780–1,790; 1,791–1,842.
    Knapp No. 3, 1,150–2,029.
    Point au Fer, 0.
    Oligocene to Recent.

Olivella mutica.
    Knapp No. 1, 1,600–1,700.
    Knapp No. 2, 1,050–1,842.
    Knapp No. 3, 1,150–1,839.
    Gymnasium, 1,200.
    Point au Fer.
    Pliocene to Recent.

Ostrea virginica.
    Knapp No. 1, 1,600–1,700.
    Knapp No. 2, 1,190–1,842.
    Knapp No. 3, 570–1,700.
    Point au Fer, 0.
    Miocene to Recent.

Pecten gibbus var. dislocatus.
    Knapp No. 1, 2,000–2,450.
    Knapp No. 3, 570–1,525.
    Miocene to Recent.

Pecten gibbus var. irradians.
    Knapp No. 1, 1,600–2,450.
    Knapp No. 2, 1,430–1,842.
    Knapp No. 3, 1,700–1,712.
    Pleistocene and Recent.

Pectunculus pectinatus.
    Knapp No. 3, 670–780.
    Pliocene to Recent.

Purpura hæmastoma.
    Knapp No. 3, 1,400–1,440.
    Point au Fer, 0.
    Pleistocene and Recent.

Rangia cuneata.
    Knapp No. 1, 2,000–2,150.
    Knapp No. 2, 1,050–1,842.
    Knapp No. 3, 0–1,800.
    Point au Fer, 0.
    Miocene to Recent.

Rangia flexuosa.
    Point au Fer, 0.
    Pleistocene and Recent

Scala lineata.
    Knapp No. 2, 1,550–1,739.
    Point au Fer, 0.
    Pliocene to Recent.

Alphabetic list of species, mainly molluscan, found in and about Terrebonne Parish, with range in depth in wells and geologic range of each species—Continued.

- Scala multistriata.
  - Knapp No. 1, 2,250-2,450.
  - Knapp No. 2.
  - Knapp No. 3, 570-1,200.
  - Pliocene to Recent.
- Strigilla flexuosa.
  - Gymnasium, 1,200.
  - Oligocene to Recent.
- Strombus pugilis.
  - Point au Fer, 0.
  - Oligocene to Recent.
- Tellina alternata.
  - Knapp No. 1, 2,443.
  - Knapp No. 3, 1,150-1,470.
  - Point au Fer, 0.
  - Pliocene to Recent.
- Tellina tenera.
  - Knapp No. 3, 0-1,470.
  - Recent.
- Terebra dislocata.
  - Knapp No. 1, 1,600-2,150.
  - Knapp No. 2, 1,050-1,739.
  - Knapp No. 3, 1,150-1,525.
  - Eocene? to Recent.
- Tornatina canaliculata.
  - Knapp No. 2, 1,050-1,790.
  - Knapp No. 3, 258-1,525.
  - Point au Fer, 0.
  - Oligocene to Recent.
- Tritonidea cancellaria.
  - Point au Fer, 0.
  - Pleistocene and Recent.
- Turbonilla interrupta.
  - Knapp No. 2, 1,050-1,790.
  - Knapp No. 3, 1,150-1,839.
  - Miocene to Recent.
- Turritella variegata.
  - Knapp No. 1, 1,600-2,250.
  - Knapp No. 2, 1,434-1,800.
  - Knapp No. 3, 1,330-1,375.
  - Pleistocene and Recent.
- Unio (Quadrula) apiculatus.
  - Knapp No. 3, 5,000.
  - Pleistocene and Recent.
- Venus mercenaria.
  - Knapp No. 2, 1,050-1,839.
  - Knapp No. 3, 570-1,550.
  - Point au Fer, 0.
  - Miocene to Recent.
- Vermetus.
  - Knapp No. 1, 2,000-2,150.
  - Knapp No. 2, 1,190-1,726.

GULF REFINING COMPANY'S WELL.

Little information is at hand regarding the well of the Gulf Refining Company on the Lirette lease near the Lirette well, in Terrebonne Parish, save that it was drilled in the winter of 1908-9, passed safely, by casing it off, the gas stratum that wrecked the Lirette well, and was pronounced a failure at 2,555 feet. The casing was pulled and the well abandoned early in 1909.

CONCLUSIONS REGARDING TERREBONNE OIL AND GAS PROSPECTS.

1. There is a great abundance of natural gas in Terrebonne Parish, but oil is practically unknown.

2. The size and geographic distribution of gas escapements and the fact that no gas of consequence has been discovered below depths of a few hundred feet in borings located near pronounced surface indications indicate clearly the lack of local dome structure. Gas, seemingly from great depths and in enormous quantities, has zigzagged its way upward from bed to bed (lying nearly horizontal or in great anticlines) and has finally made itself manifest at the surface, not immediately above great "pools," but wherever the line of least resistance may have led.

3. Tertiary beds may possibly in some places be within 2,000 feet of the surface, though apparently nowhere much above that level. Quaternary beds evidently in places lie at more than 3,000 feet below the surface.

4. The utilization of the gas awaits the invention of some method of properly setting a casing where there is no cap rock or other natural firm bed to serve the same purpose.

EXPLOITATION IN LOUISIANA WHERE NEITHER SALINE DOME NOR STRATUM OIL OR GAS COULD WELL BE EXPECTED.

ACADIA PARISH.

CROWLEY.

The Rice Company's oil well, 1 mile west of Crowley, was sunk in the winter of 1902-3 to a depth of 2,015 feet without obtaining oil or gas. Mr. Gregg, of Crowley, furnished the record of the lower portion of the well. It is as follows:

Partial record of Rice Company's oil well, Crowley.

	Feet.
Medium fine oil sand	1,640-1,650
Extremely fine oil sand	1,650-1,660
Coarser oil sand	1,660-1,675
Very coarse sand	1,700
Green and brown clays	1,810
Four inches of rock	1,940
Green and brown clays	2,015

The mouth of the well is about 19 feet above sea level. The drilling outfit was removed in February, 1903, to the North Star well site, 3 miles north of Crowley.

Duson Brothers were reported to have attained a depth of 3,000 feet in a well 1 mile northeast of Crowley June 18, 1905.

ESTHERWOOD.

A showing of oil was reported from the Delcambre Oil and Mineral Company's well, Estherwood, at a depth of 400 feet, March 6, 1909.

IOTA.

The Foley Oil Company was reported, February 3, 1907, as deepening an old 2,000-foot hole near Iota; was about ready to set a strainer.

ASSUMPTION PARISH.

LABADIEVILLE.

About a mile southeast of Labadieville station, on the Napoleonville branch of the Southern Pacific Railroad, two test wells were put down in 1902 and 1903 by the Assumption Oil and Mineral Company.

The wells were but 20 feet apart. The log of the first, as given by Morton Rhodes, of Napoleonville, is as follows:

Log of first well of Assumption Oil and Mineral Company near Labadieville.

	Feet.		Feet.
Soil and clay	150	Gravel	845
Gumbo and sand	200	Sand	890
Sand and gravel	290	Rock and shells	908
Bowlders in sand	340	Quicksand	930
Sand and sandstone	390	Clay and shells	970
Sand and gravel	440	Sand and bowlders	995
Rock	480	Blue gumbo	1,090
Oil sand	510	Sand and bowlders	1,145
Gravel	540	Oil sand	1,190
Clay	565	Sand and gravel	1,220
Sand and rock	600	Sand	1,385
Coarse sand	665	Sand and gravel	1,430
Gumbo and clay	675	Gravel	1,510
Gravel	695	Sulphur and clay	1,730
Rock	700	Oil sand	1,800
Gumbo	730	Sulphur, clay, shells	1,850
Sand and blue shale	745	Rock, sand, and sulphur	2,000
Sand and gravel	780	Sand	2,100
Gravel and bowlders	800	Rock (drill broken).	

Captain Pickard supplied the following detailed statement of the occurrence of strata beneath 1,820 feet in the second well:

Partial log of second well of Assumption Oil and Mineral Company near Labadieville.

	Ft.	in.		Ft.	in.
Gumbo and shells	1,830		Gumbo and shale	1,997	9
Sand with oil	1,846	5	Gumbo	1,999	5
Rock	1,847	1	Rock	2,000	3
Sand and oil	1,865	11	Gumbo, shells, oil	2,019	8
Gumbo	1,873	11	Shale and shells	2,037	9
Shale and gumbo	1,884	1	Sand, shells, and gumbo	2,057	5
White sand and some oil	1,903	6	Gumbo	2,059	11
White sand	1,915	6	Water sand	2,096	5
Gumbo	1,922	9	Gumbo	2,102	5
Sand and gumbo	1,927	9	Rock	2,102	9
Rock	1,928	5	Gumbo	2,115	11
Salt-water bed	1,945	3	Gumbo	2,129	11
Sand and gumbo	1,961	1			

NAPOLEONVILLE.

The J. M. Guffey Petroleum Company put down a well near Avoca, a station on the Napoleonville branch of the Southern Pacific Railroad, during the fall of 1906, reaching a depth of 2,240 feet and finding cold salt water. Heywood Brothers repeated the test in January and February, 1907, reaching a depth of about 2,000 feet, with similar results.

AVOYELLES PARISH.

More or less detailed sections of the Natchez and Marksville well at Marksville have been given in Bulletin 1 of the Louisiana Geological Survey and Professional Paper 46 of the United States Geological Survey. These sections extend only to a depth of 1,283 feet. O. W. Myers, the driller, has furnished, under date of March 31, 1904, a record of the well to 2,631 feet, as follows:

Log of Natchez and Marksville well, Marksville.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, clay, red	18	18
Red sand, very fine	24	42
Coarse sand	108	150
Sand rock	4	154
Coarse sand and bowlders	24	178
Sand rock	5	183
Bowlders	3	186
Sand and gravel	16	202
Red clay	6	208
Fine sand	7	215
Sand, coarse and round	8	223
Red clay	8	231
Rock	½	231.5
Sand and clay in thin layers	8½	240
Gravel	27	267
Blue clay with bowlders	59	326
Blue laminated clay	15	341
Clay, red and tough	4	345
Blue clay	21	368
Blue laminated clay	21	389
White sand	10	399
Blue clay	15	414
Blue laminated clay	12	426
White sand	8	434
Blue laminated clay	27	461
Coarse sand	71	532
Very tough blue clay	103	635
Shells in blue laminated clay	8	643
Blue clay	14	657
Laminated blue clay	18	675
Sand rock	1	676
Clay, more or less laminated, blue	38	714
Clay, brown, laminated; some sand	60	774
Clay	10	784
Sand and laminated clay	16	800
Laminated clay	5	805
Coal (lignite)	1	806
Very tough clay	20	826
Rock	2	828
Clay and bowlders	71	899
Coarse sand	50	949
Soft sandstone	40	989
Sand	18	1,007
Hard sandstone	28	1,035
Sand, gravel, and bowlders	84	1,119
Hard limestone	1	1,120
Clay	58	1,178
Limestone	2	1,180
Clay	100	1,280
Iron pyrites	4	1,284
Limestone	4	1,288
Clay	62	1,350
Bowlders and pyrites	4	1,354
Clay	18	1,372
Sand and laminated clay	38	1,410
Clay	16	1,426
Hard sandstone	4	1,430
White sand	4	1,434
Laminated clay	21	1,456
Clay	32	1,488
Laminated clay	17	1,505
Clay, tough and hard	26	1,531
Laminated clay	60	1,591
Sandstone	8	1,599
Brown laminated clay with woody fragments and sand	41	1,640
Clay	22	1,662
Sand, fine and yellow	16	1,678
Laminated clay	26	1,704
Clay with thin limestone layers	14	1,718
Laminated clay, with shells	1	1,719
Clay	10	1,729
Clay, laminated with sand	42	1,771
Clay	22	1,793
Clay, brown, laminated	8	1,801
Limestone, very hard	½	1,801.5
Clay	4½	1,806
Clay, blue, laminated	18	1,824
Laminated clay, almost white	57	1,881
Clay, very hard and tough	19	1,900
Sand or fine gravel	2	1,902
Clay	24	1,926
Clay, dark brown, laminated	1	1,927
Clay with thin hard seams	94	2,021
Sand, coarse, white	80	2,101
Clay, very hard and tough	36	2,137
Laminated clay, blue and brown	16	2,153
Clay	31	2,184
Clay, blue, laminated	13	2,197
Clay, dark brown, laminated with some sand	20	2,217
Clay, very tough	22	2,239
Clay, hard joint, dry	16	2,255
Clay	9	2,264
Clay, dark, laminated	9	2,273
Sandstone	21	2,294
Sand and laminated clay	17	2,311
Sandstone, soft	20	2,331
Sand and wood, very firm when first taken out	45	2,376
Clay, blue, green, and red	127	2,503
Brown clay, hard laminæ, lignite	44	2,547
Sandstone, soft, black	38	2,585
Clay	22	2,607
Clay, laminated, with some sand and wood	24	2,631

The above is as near correct as the log can be kept where the drilling is done with the rotary process. Of course it is impossible to know to the inch the thickness of any soft stratum; but where it is hard we know the exact thickness.

The difference between this record of the well and that credited by Veatch to the driller, A. W. Myers (evidently misprint for O. W. Myers), in Professional Paper 46, is noteworthy. The record obtained by the writer in the field from samples and statements by those who were present at the time the well was put down to the depth of 1,283 feet agrees in general more closely with Veatch's record than with the one given above. However, the record from 1,283 to 2,631 feet is new and is interesting as showing that probably the basal members of the Catahoula formation are not reached at that depth. No thick beds of soft white sandstone are here recorded. The material penetrated in the lower part of this section is interpreted as the more or less lignitic sands and clays that accumulated in the upper Oligocene fresh-water trough whose northern marginal representatives constitute the Catahoula deposits. It is certainly a great pity that the "shells" encountered between 1,718 and 1,719 feet could not have been preserved and submitted to some competent authority for identification. Nowhere in Louisiana is there greater need for paleontologic data to assist in working out the general stratigraphy of the State.

BOSSIER PARISH.

> The Busch-Everett test on the L. C. Bulkley land, sec. 8, T. 19, R. 13, Bossier Parish, is below 2,800 feet and is still grinding. The Gulf Companies test on the Oakland plantation, sec. 16, T. 17, R. 11, Bossier Parish, is reported to be about 1,200 feet without results.—Oil Investors' Journal, September 6, 1909.

The location and a section of the well at Plaindealing have already been given in connection with the description of the Caddo field (p. 154.)

CADDO PARISH.

The Rhodessa Land and Development Company commenced a well early in 1908 in the northernmost part of Caddo Parish. No results are yet reported.

CALCASIEU PARISH.

CASTOR SPRINGS.

A test well was sunk at Castor Springs 25 miles north of Jennings, in Calcasieu Parish, by Houston people.[a] It was abandoned at 2,100 feet April 5, 1907. It had a small gas showing.

DE RIDDER.

The McMahon prospect hole at De Ridder developed salt water January 18, 1905.

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[a] Oil Inv. Jour., November 3 and December 3, 1906.

EDGERLY.

A test hole reaching a depth of 1,900 feet or more, put down by the Higgins Oil and Fuel Company in the NW. ¼ SW. ¼ sec. 28, T. 9 S., R. 11 W., blew out sand and salt water for two hours December 20, 1907. A second hole, 400 feet north of the first, was abandoned at 1,800 feet in February, 1908. A third, 1,000 feet south of the first, gave salt water and was abandoned.

FENTON.

Near Fenton, in sec. 18, T. 8 S., R. 5 W., a dry hole was sunk to 2,010 feet.

KINDER.

In the vicinity of Kinder several tests have been made for oil. In sec. 33, T. 6 S., R. 6 W., the Pearl Oil and Lumber Company obtained some showings of oil at 988 and 1,200 feet, but cased them off and went on to 2,009 feet, the depth contracted for. In the second hole by this company, drilled to 1,500 feet, "the drill went through 750 feet of gumbo, shale, and clay, without any showing of sand except 3 feet of clear white sand (no water) between 1,248 and 1,251 feet. Quantities of pyrites of iron were encountered four or five times, and in fact it appeared on the clay or gumbo. The drill was stopped in hard clay." The Vickers well showed considerable oil at 1,300 feet, but this was cased off and the hole deepened to 2,280 feet without results.[a]

LAKE CHARLES.

In 1901 two wells were sunk in the vicinity of Lake Charles. One, the Watkins No. 1, in sec. 16, T. 10 S., R. 8 W., though more than 2,400 feet deep, showed no signs of having penetrated Pleistocene formations, all the fossils found belonging to Recent species. In the Louisiana Geological Survey's report for 1902, page 270, a detailed section of this well is given. The well at Hoo Hoo Park was sunk to 1,800 feet and abandoned. In the summer of 1909 the Lake Charles Oil Company began operations on the Liedig farm, 2 miles southeast of the two wells just mentioned, but work was abandoned in August, 1909.

LAKE ARTHUR.

Log of the Mermentau River Oil Company's well near Lake Arthur.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Top soil and clay	18	18	Sand	157	1,039
Red quicksand	20	38	Soft gumbo clay	158	1,197
White quicksand	95	133	Hard gumbo clay	79	1,276
Red shale and shell	37	170	Gravel, sand	135	1,411
White quicksand	40	210	Hard gumbo clay	22	1,433
Blue shale	36	246	Blue shale	22	1,455
Water sand	42	288	Gumbo clay	41	1,496
Sand and gravel	37	325	White sand	20	1,516
Coarse gravel, sand	302	627	Hard gumbo clay	198	1,714
Blue gumbo clay	37	664	Gumbo clay, shale	19	1,733
Coarse gravel	38	702	Oil sand, shale	16	1,749
Blue gumbo clay	180	882	Oil sand, gumbo clay	58	1,807

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[a] Oil Inv. Jour., November 19, December 5, 1907, May 19, 1908.

After penetrating into the pocket of oil sand at 1,700 feet the showing of oil was continuous. The first gas pressure noticeable was encountered at 550 feet. Below 1,400 feet demonstrations were frequent, and after the screening had been placed gas roared in the pipe. The well is finished with a 4-inch pipe, screened 100 feet. A 6-inch casing is down 1,400 feet and an 8-inch casing is down 660 feet. Rotary, August 13, 1903.

SERPENT BAYOU.

The vicinity of Serpent Bayou has been looked upon as showing favorable oil signs, especially by the Barnett Brothers, of Lake Charles. The Crowley Oil and Sulphur Company is said to have a well here 2,000 feet deep, showing signs of oil and some sulphur (August 20, 1908).

ROANOKE.

Gen. J. B. Weaver put down a test well north of the Roanoke railway station in the spring of 1903 without results.

The Shippers' Oil Company is credited with drilling a well near this place to a depth of about 2,800 feet, obtaining gas and some oil indications (February 3, 1907).

SULPHUR.

A well 8 miles north of the mine at Sulphur is reported as abandoned at 1,200 feet (April 18, 1906).

Gas is reported in water wells 6 miles north of Sulphur (January 20, 1908; March 6, 1908).

The test hole on the Kerr tract, 1 mile north of the Sulphur mine, 1,000 feet deep, showed no traces of sulphur (September 19, 1907).

The Meathers Oil Company's test hole on the Eddy and Gunn place, 7½ miles north of the mine, was closed up at 1,750 feet in June, 1909.

CAMERON PARISH.

A test well was reported as being drilled on Johnsons Bayou by Fred. Pavell June 20, 1909.

CATAHOULA PARISH.

LELAND.

Two deep wells have been sunk in Catahoula Parish for oil, one at Leland, another at Trout. The former was investigated by the United States Geological Survey, and described by Veatch [a] as follows:

> Mr. Thomas W. Robertson, field assistant, visited this well August 18, 1902, and obtained from Mr. A. A. Arnold, head driller, and Dr. J. C. Harden, fossils found at a depth of 1,000 to 1,250 feet. These have been pronounced Jackson (Eocene) by Prof. G. D. Harris. The depth at which they were found confirms the dip observations made on Ouachita River between Stock Landing and Carter Landing.
>
> Doctor Harden, with whom the drillers stayed, was greatly interested in the well and kindly allowed Mr. Robertson to copy the following from his personal memo-

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[a] Veatch, A. C., Prof. Paper U. S. Geol. Survey No. 46, 1906, pp. 292-293.

randum. It should be noted that it differs materially from the record furnished by the president of the company, and given below, which on the whole more nearly agrees with the known structure.

Section of well of Catahoula Oil and Development Company, Leland, Catahoula Parish, La.

[By Dr. J. C. Harden.]

	Feet.
No record	0 - 40
Coarse gray sandstone, containing pure freestone water	40 - 60
Black clay, with pebbles	60 - 70
Soft sandstone, with water	70 - 246
Dark-green clay	246 - 546
Sandstone	546 - 559
Coarse red and white sand	559 - 601
Black and yellow clays	601 - 666
Soft sandstone	666 - 670.5
Sand, with soft, warm water	670.5- 700.5
Black clay	700.5- 760.5
Yellow clay	760.5- 775.5
Fine gray sand, with water	775.5- 800.5
Black clay	800.5- 875.5
No record	875.5-1,000
Clay, with shells (Jackson)	1,000 -1,250
No record	1,250 -1,300
Very black formation, old seaweed, mud, and lignite (Cockfield)	1,300 -1,500
Sand, with artesian salt water	1,500 -1,645
Rock, "gypsum"	1,645 -1,651
Very fine gray gypsum?; sand; water not artesian	1,651 -1,701
Black and yellow clay	1,701 -1,751
Rock	1,751 -1,764
No record	1,764 -1,864

"Pipe was withdrawn from 1,864 to 900 feet, when an explosion occurred which could be heard over three-fourths mile; then a gusher of very foul-smelling gas, mud, lignite, and salty water shot up over 100 feet. This contained some oil. Flow continued for twenty-two hours, when it stopped by choking. Before flow stopped salty water became quite clear."

The president, Mr. S. McDowell, furnished the following record in February, 1903:

Section of well of Catahoula Oil and Development Company, Leland, Catahoula Parish, La:

[By S. McDowell, president.]

	Feet.
Gray-mottled clay	0- 60
Quicksand, with water	60- 80
Sandstone	80- 130
Blue or green clays	130- 370
Water-bearing sand	370-
Blue or green clays	-1,550
Artesian salt water	1,550-

No water was encountered between the 370-foot sand stratum and 1,550 feet.

TROUT.

William Buchanan employed the Clifford Well Company to drill a well 2,400 feet deep at Trout, Catahoula Parish. The best indications were said to occur at 1,925 feet. Large quantities of soft gypsum are reported (July 6, 1909).

EAST BATON ROUGE PARISH.

DEERFORD.

The Baton Rouge Oil and Natural Gas Company's well at Deerford 6 miles east of Zachary, 17 miles north of Baton Rouge, was down 2,300 feet September 1, 1909. Capt. M. H. Pickard was the driller. Several gas pockets were reported.

ZACHARY.

The Tucker Oil Company's test at Zachary, La., near Baton Rouge, was 1,400 feet deep September 1, and drilling with a 5¾ inch bit. Logs were penetrated in the hole at 60, 900, and 1,200 feet.—Oil Investors' Journal, September 6, 1909.

GRANT PARISH.

Gas has been noted in a water well at Colfax (February 6, 1909). The Colfax and Caddo Oil and Gas Company was reported to be drilling at Colfax, June 20, 1909. In view of these enterprises the log of the town well, as interpreted by Veatch,[a] may be of interest.

Section of town well at Colfax.

[By L. B. Hart.]

	Feet.
Port Hudson:	
Surface	0– 70
Water-bearing sand and gravel	70– 130
Jackson:	
Very hard clay	130– 300
Blue joint clay	300– 550
Cockfield:	
Fine quicksand	550– 650
Hard brown clay	650– 800
Sand rock	800– 835
Alternate layers of quicksand and black clay	835–1,000
Sand rock	1,000–1,060
Loose sand	1,060–1,100
Hard sandstone	1,100–1,128
Hard white clay, not passed through	1,128

"Pipe pulled back and set at 1,103 feet. This water proved to be very salty or full of soda. It seemed to be propelled by gases, the water rising in a pipe 65 feet above the surface. The natural flow is 60,000 gallons for twenty-four hours."

Mr. R. S. Cameron reports that below 150 feet gypsum and shells (principally small spirals) were quite common. No shells were found above 150 feet.

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[a] Veatch, A. C., op. cit., p. 297.

IBERIA PARISH.

On account of certain seepages on the Lydia plantation, near New Iberia, Messrs. Lucas, Knapp, and others put down a test well to a depth of 1,900 feet in the fall of 1908. Below 700 feet, according to Mr. Lucas, compact clay predominated and no signs of gas or oil were found.

LAFAYETTE PARISH.

BROUSSARD.

The Lafayette-Crowley Oil Company is reported to have found a bed of "coal" in its test well 4 miles west of Broussard, at a depth of 290 feet (April 20, 1909).

LAFAYETTE.

A 1,500-foot test well was sunk on the André Martin tract, The Magnolias, 2 miles southeast of Lafayette, without obtaining oil indications, in the summer of 1903.

LINCOLN PARISH.

In passing through Ruston the writer has on several occasions examined the materials brought out of the water and oil wells, but has seen no reason for supposing that there is a local uplift of any consequence in this vicinity. The fossils obtained are all of a lower Claiborne horizon, although coming from depths of more than 700 feet. The following special dispatch to the Oil Investors' Journal under date of August 23, 1907, sums up the situation as generally understood in Ruston:

> The Ruston Oil and Development Company's test well on the Ruston, La., waterworks lot has reached a depth of 1,879 feet, the last 400 feet in gray, shaly clay, interlaid with sandstone and thin layers of limestone. Above 1,500 feet showings of oil were reported in five places. At 785 feet a streak of pay was found estimated to be good for 5 to 10 barrels a day. At the same depth oil was developed in the city well, and before it was cased off about 10 barrels came out on the water, also gas with the odor of oil. This created excitement and made it difficult to secure land. Money was at one time raised to go after the oil. L. B. Clifford, of the L. B. Clifford Well Company, is drilling the well.

OUACHITA PARISH.

MONROE.

A test well was started for "oil, gas, and water" in Forsythe Park, Monroe, in the summer of 1909, by Harper and Snell (Oil Investors' Journal, June 20, 1909). Much gas was encountered at 1,300 feet. The well was deepened to 1,500 feet and found large quantities of salt water (August 20, 1909).

CHENIERE.

The so-called Louisiana Oil Company, Consolidated, drilled a shallow well in Cheniere Brake, in the southeastern portion of sec. 11, T. 2 E., R. 17 N., shortly after the first excitement over oil prospects in the Gulf States caused by the remarkable results at Spindletop, Tex. A section of this well is given by Veatch in Professional Paper 46, page 303. The writer personally visited this place while operations were delayed for various reasons difficult to ascertain. Though a depth of 1,000 feet or more was claimed for the well, no material coming from it contained any but lower Claiborne (St. Maurice formation) fossils. They may here extend to a depth of 500 feet. Veatch gives the section to 515 feet.

PLAQUEMINE PARISH.

The well of the Algeria Oil Company at Algeria was down 1,718 feet June 6, 1909, with slight oil and gas indications. Two thin rocks were penetrated.

RAPIDES PARISH.

ALEXANDRIA.

Several well sections at or near Alexandria were published as early as 1906. One of these was made up from samples furnished by Oscar Shanks and shows clearly the great depth of the Catahoula formation at this place. Certainly no local doming is implied by this section, which is herewith republished. It seems, however, not to have deterred prospecting in this vicinity, as the notes appended below clearly attest.

Samples from asylum well, Pineville.[a]

	Feet.
Medium to coarse reddish-yellow quartz sand	20- 24
Fine white indurated sand	24- 35
Very fine light-gray sandy silt	52- 92
Clay conglomerate, composed of small rounded clay pebbles containing considerable lime	228- 324
Fine-grained white sand	324- 328
Light-gray clay with rounded calcareous clay pebbles	328- 428
Hard gray fine-grained quartzitic sandstone	455- 461
Green clay	461- 540
Green clay and fine gray sand	540- 610
Green clay and fine gray sand, with numerous thin calcareous plates that resemble shell fragments, but which can not be definitely proved to be of organic origin	610- 650
Greenish-gray clayey sand	720- 800
Medium white sand, with a little clay	800- 806
Very fine gray clayey sand	806- 925
Rounded white calcareous concretions, lignite and gray laminated lignitic sand	927
Greenish clay, lignite and sand; a few thin white calcareous plates similar to those in the 610-650 foot zone	925- 985
Fine greenish-gray sand	985-1,020

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[a] Veatch, A. C., Prof. Paper U. S. Geol. Survey No. 46, 1906, p. 311.

Brown Brothers completed a test well to 2,600 feet, but found no oil (Oil Investors' Journal, March 5, 1908).

The Central Louisiana Oil and Development Company's well at Alexandria was down 1,200 feet February 7, 1907; found a showing of oil and gas April 5, 1907; reached 2,500 feet December 5, 1907; was completed at 2,600 feet, with no oil, March 5, 1908.

Gas was said to issue from the Bentley Hotel well at 1,069 feet May 6, 1909.

CHENEYVILLE.

Oil and gas showings were reported from a well 1,400 feet deep 5 miles west of Cheneyville May 19, 1908; the well had attained a depth of 1,900 feet September 6, 1908.

RED RIVER PARISH.

> Atkins Brothers are preparing to go deeper with the test they drilled at Coushatta, La. The hole is now 1,200 feet.—Oil Investors' Journal, June 19, 1907.

ST. LANDRY PARISH.

EUNICE.

The Wilfert Development Company, organized in 1907, in a test hole near Eunice passed through an 8-foot rock stratum at a depth of about 650 feet, then through 1 foot of clay into quicksand containing gas (January 6, 1909). The well was down 1,820 feet, with oil and gas showing, April 6, 1909.

MELVILLE.

The following section of the Latannier Oil Company's well, 12 miles south of Melville, from notes furnished by Oscar Shanks, driller, may be of value to prospective operators in this section of the country:

Section of Latannier Oil Company's well 12 miles south of Melville.[a]

	Feet.
River deposit	0-20
Blue clay	20-150
Gravel and bowlders	150-232
Hard, blue flinty rock	232-336
Caving brown gravel	336-532
Hard, blue flinty rock	532-537
Coarse blue sand with a large flow of pure, soft water	537-555
Gumbo shale	555-1,452
Pepper-and-salt sand, with a strong flow of water having a slight sulphur taste	1,452-1,458
Strata of gumbo and rock containing strong artesian sulphur water	1,458-2,003

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[a] Veatch, A. C., op. cit., p. 314.

OPELOUSAS.

In drilling for artesian water at Opelousas, La., Brown Brothers encountered a showing of oil between 600 and 700 feet and at 750 feet they had a blowout which sent the water 40 feet into the derrick.—Oil Investors' Journal, April 5, 1907.

The Plaisance Oil Company started a well on the Cretin farm, 3 miles southeast of Washington and 6½ miles north of Opelousas, November 10, 1908. Considerable gas was struck at 1,100 feet.

ST. TAMMANY PARISH.

The Sulphur Oil, Sulphur, and Mineral Company sank a test well to 2,500 feet without results December 3, 1906, on the Garland tract, Covington.

The St. Tammany Oil Company put down a well at Covington 2,700 feet without results July 19, 1907; W. H. Lovegrove, driller.

The Oak Ridge Oil Company was testing 13 miles west of Covington September 6, 1909.

VERMILION PARISH.

ABBEVILLE.

S. T. Hurst, drilling for the Perry Oil and Mineral Company on the farm of Alcide Le Blanc at Perry's bridge, 1½ miles east of Abbeville, La., set the 6-inch at 630 feet May 31; 20 feet of oil-bearing sand at a depth of 2,350 feet, August 6, 1909. The Abbeville Oil and Mineral Company drilled a test to 2,400 feet, 30 miles from the present site.—Oil Investors' Journal, June 20, 1909.

GUEYDAN.

The Wilkinson Development Company was reported as drilling a test hole 4 miles south of Gueydan March 20, 1909.

VERNON PARISH.

A well near Hornbeck, on the Kansas City Southern Railway, being drilled by Mr. Savage, was reported to have attained a depth of 500 feet September 3, 1906.

WEBSTER PARISH.

Drilling was reported at a point 17 miles north of Minden, by the Webster Parish Oil and Gas Company.—Oil Investors' Journal, May 19, 1908.

WINN PARISH.

Winnfield has justly been considered an interesting locality from a geologist's standpoint for many years. The peculiar dome structures showing at the surface as "salt licks" and the marble quarry are discussed elsewhere (p. 25). In the immediate vicinity of the town the Vera well has been sunk to a depth of 1,000 feet without showing any influence of the local uplifts. Mr. W. F. Cooper, the moving spirit in this enterprise, has kindly furnished the log of the well to 1,000 feet (see below), with the following remarks: "The well is in the northwest corner of the SW. ¼ SW. ¼ sec. 24, T. 11 N., R. 3 W. I did not strike any salt water, and have set casing at 1,000 feet. I have made arrangements to go 500 feet farther." The shells mentioned in the log between 700 and 800 feet were forwarded to the writer and prove to be mid-Claiborne (Eocene) species. Therefore, as Cretaceous rocks undoubtedly come close to the surface but 3 or 4 miles to the east or west it is clear that this locality is in one sense in a synclinal trough, and prospects for oil or gas are practically eliminated.

Partial log of Vera well, Winnfield.

	Thickness.	Depth.
	Feet.	*Feet.*
Sandy soil	6	6
Sand; flow of water	32	38
Sand (gray)	24	62
Sand, with thin strata of clay and sand rock	48	110
Sand, with thin strata of shale	150	260
Rock	3	263
Hard shale	35	298
Soft shale (blue)	34	332
Hard rock	2	334
Shale	4	338
Sand rock	3	341
Soapstone	4	345
Shale and rock strata	20	365
Shale and soapstone	12	377
Shale and layers of shale	27	404
Shale, hard and soft	16	420
Sand and layers of rock	23	443
Hard shale	3	446
Rock	2	448
Hard shale	2	450
Soapstone	9	459
Hard shale	18	477
Hard rock	2	479
Soapstone	19	498
Gray shale, thin layers of soapstone	23	521
Gray water sand	36	557
Shale, thin sand layers	47	604
Hard shale	13	617
Rock formation	6	623
Fine gray sand	19	642
Shale and thin layers of fine sand	32	674
Hard shale	11	685
Red gumbo (stiff)	13	698
Fine sand, shells, and shale	17	715
Hard shale and shells	11	726
Hard rock	3	729
Fine sand and shells	51	780
Shale, thin layers of fine sand	27	807
Red gumbo (stiff)	5	812
Shale and shells	4	816
Fine gray sand	12	828
Fine sand and shells mixed	13	841
Rock	5	846
Shale with layers of gumbo	74	920
Gumbo (blue)	14	934
Shale and layers of gumbo	12	946
Hard rock	1	947
Layers of shale and rock	9	956
Hard shale and layers of gumbo	26	982
Red gumbo (stiff), changing to blue	18	1,000

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